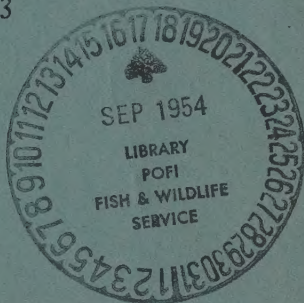


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A CONTRIBUTION TO THE LIFE HISTORY OF THE SWORDFISH, *XIPHIAS GLADIUS* LINNAEUS, FROM THE SOUTH ATLANTIC COAST OF THE UNITED STATES AND THE GULF OF MEXICO.

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ABSTRACT

Thirty three postlarval specimens of swordfish, *Xiphias gladius* Linn., from the South Atlantic coast of the United States and the Gulf of Mexico, ranging in standard length from 6.1 mm to 192.1 mm are discussed. Nine specimens are illustrated and fourteen detailed descriptions are given, bringing together developmental characters for the range presented. Ten adults from Cuba and four from Canada are used to establish characteristic adult body proportions. The range of adult fish is given and the occurrence of females with varying stages of ovaries is mentioned. A hypothesis on the spawning time and area for the region concerned is given as taking place from the lower Caribbean to the South Carolina coast, probably year round, with the height of the season in Florida and Georgia waters from April through September. The stomach contents of 27 larval specimens are analyzed, and temperature, salinity and oxygen concentrations are given for stations occupied along the approximate axis of the Gulf Stream.

INTRODUCTION

The South Atlantic Fishery Investigations is a cooperative program of the U. S. Fish and Wildlife Service participated in by the U. S. Navy Hydrographic Office, the office of Naval Research, the Georgia State Game and Fish Commission, and The Marine Laboratory, University of Miami, acting for the Florida State Board of Conservation. This program is a biological, chemical and physical oceanographic survey of the waters from off the beaches to beyond the axis of the Gulf Stream, in the area between the Straits of Florida and Cape Hatteras,

¹Contribution No. 128 from the Marine Laboratory, University of Miami.

Note: Research resulting from the Cooperative South Atlantic Fishery Investigations.

North Carolina. For use in this investigation the Fish and Wildlife Service furnishes the *Theodore N. Gill*, a ninety-seven foot research vessel. Four to five cruises are conducted per year occupying eighty regular stations, nine special stations and one standard station on each cruise. As a result of the first four cruises, from February to November, 1953, twenty-seven specimens of swordfish, *Xiphias gladius*, Linn. ranging from 7.8 mm to 192.1 mm were captured.

At this time the author wishes to express his appreciation to W. W. Anderson of the Fish and Wildlife Service for his help and guidance in the development of this study; to Mr. Jose A. Suarez of the Centro De Investigaciones Pesqueras, Havana, Cuba, and to Capt. C. J. d'Entremont of Lower West Pubnico, Nova Scotia, who graciously supplied measurements of adult fish; to E. L. Arnold of the Gulf Fishery Investigations, Galveston, Texas, who loaned five larval specimens captured from the U.S.F.W.S. vessel *Alaska* in the Gulf of Mexico; and to coworkers of the fish life history group of The Marine Laboratory of The University of Miami for assistance in the course of this present study. Also acknowledgements are given to members of the Fish and Wildlife Service staff and other cooperators at the Brunswick, Georgia, field station, and to the Marine Laboratory of The University of Miami for the financial assistance which made this paper possible.

Although some of the early life history of the swordfish is known from the Mediterranean (Sanzo, 1910; 1922; 1930; and Sella, 1911), there never has been established any other spawning ground than the Straits of Messina in the Mediterranean. Reports as far back as Cuvier and Valenciennes (1931) picture small swordfish. Lutken, (1880) found numerous larvae in the North and South Atlantic, but the information was so scattered that no area could be positively identified as the main spawning grounds. LaMonte, (1944) reports ripe ovaries from the north coast of Cuba and postulates that this region is to be suspected as a possible spawning area. Small swordfish have been reported from the Gulf Stream system in the past, LaMonte and Marcy, 1941, but the group under consideration in this paper is the largest number taken in such a short period of time and over such a regular pattern.

In the course of the paper representative larval stages are illustrated and described in detail and percentages of standard length and body proportions are discussed. Indications of growth from larval to adult stages are made and some general biological data are presented; all of

this contributing to the biology of the swordfish along the South Atlantic coast of the United States and the Gulf of Mexico.

COLLECTIONS, METHODS AND DEFINITIONS

Collection of Specimens. All of the larval specimens, with one exception, were taken either by dip-net or by plankton tow; the former method providing the majority of the specimens. The 192.1 mm specimen was taken from the stomach of a dolphin (*Coryphaena hippurus*), which had been captured on the trolling lines (Table 1 and Figure 1).

Dip-net fishing was carried on as part of the regular operations on all stations and in this case proved most rewarding during the daylight hours. Only three of the specimens were captured during darkness. The dip-nets in use were constructed from fourteen-foot calcutta bamboo poles, fitted with an eighteen inch loop of three-eighths inch aluminum tubing. A two-foot cone of three-sixteenths inch stretch nylon mesh, backed by a similar cone of one inch stretch cotton mesh, was attached to the loop. These nets were extremely light and quite easily managed.

Where possible, seventy-meter oblique plankton tows were taken on each station with the Gulf III all-metal plankton sampler (Arnold & Gehringer, 1952). One specimen 12.1 mm in length was captured by this method on station 29 of cruise 3. A special thirty-minute surface tow was made on station 30 of cruise 3 and resulted in the capture of three small specimens (9.0 mm, 14.5 mm and 20.8 mm).

All of the specimens captured by dip-net were preserved in five percent buffered formalin. In all cases the vials were placed on their sides to try and maintain the natural condition of the specimen. All plankton material was preserved with five percent buffered formalin. In all cases the original color density remained unchanged, but the characteristic blue pigment faded.

Methods of Measurement. All measurements except snout to the fin origins were made on specimens from 9.0 mm to 22.1 mm with a micrometer eyepiece whose units had been calibrated against a fine millimeter rule. From the 34.4 mm specimen on, all measurements except eye diameter, the five depth measurements, and the anal and pectoral base were made by marking off the lengths on a millimeter grid. These were then checked with screw-type calipers and marked off on a fine millimeter rule. The dorsal base was measured in this manner from the 18.2 mm specimen on.

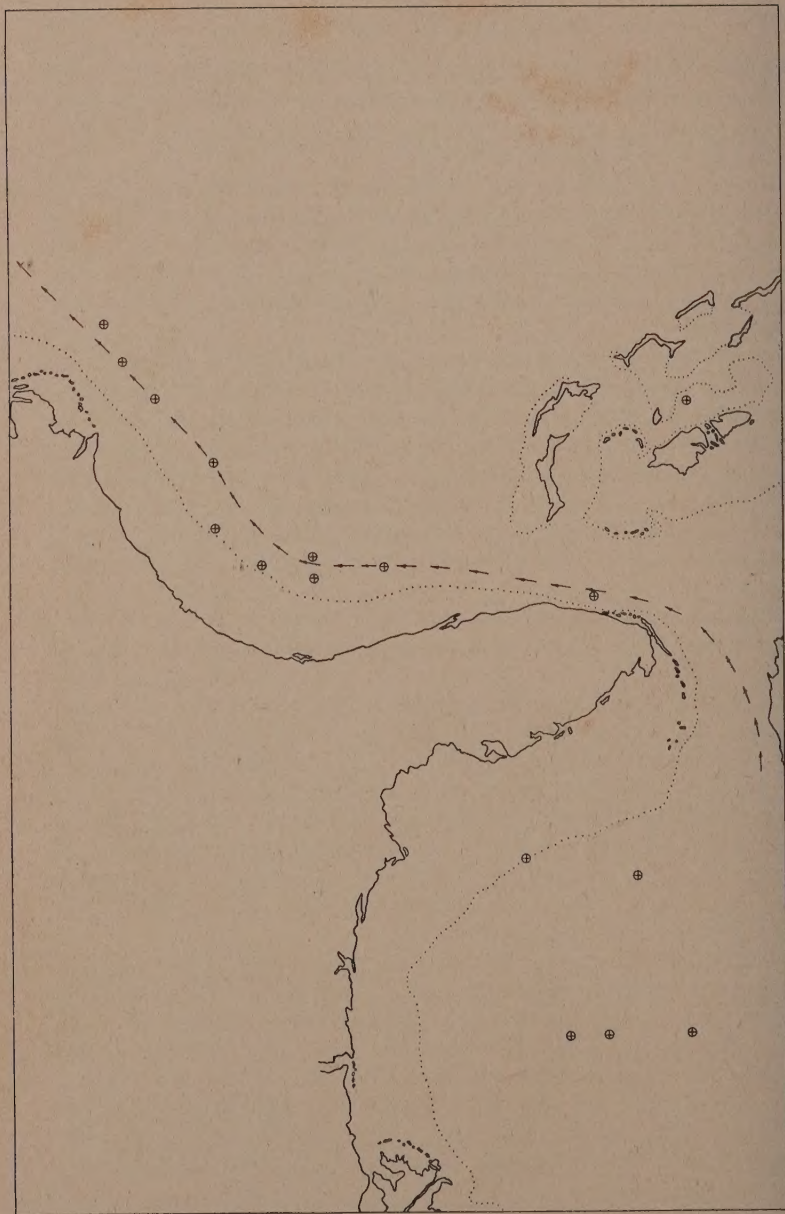


FIGURE 1. Chart of South Atlantic Coast of the United States and the Gulf of Mexico indicating location of capture of larval swordfish. Circles with crosses represent areas of capture of larval swordfish, dotted line represents one hundred fathom curve and arrows represent approximate axis of Gulf Stream.

TABLE 1. DATA ON THE CAPTURE OF SWORDFISH SPECIMENS.
U.S.F.W.S. T.N. GILL Cruise 2

Station No.	Date	Location of Capture		Time of Capture	Specimen No.	Size in mm	Method of Capture
		Lat. N	Long. W				
17	April 25, 1953	29° 40'	79° 36.8'	1650	Reg. 17	68.8	Dip net
39	May 5, 1953	31° 40'	79° 22'	0945	Reg. 39	33.0	"
53	May 7, 1953	32° 50'	78° 05'	1253	Reg. 53	70.0	"
61	May 8, 1953	32° 54'	77° 04'	1300	Reg. 61	28.6	"
72	May 10, 1953	33° 52'	75° 59'	0230	Reg. 72	72.5	"
73	May 10, 1953	34° 16'	75° 18.5'	1050	Reg. 73	7.8	70 meter oblique plankton tow
Between 80 & Sp. Sta. 1	May 12, 1953	34° 28.5'	74° 38.5'	1530	S.C.	192.1	Stomach contents of <i>Coryphaena hippurus</i>
U.S.F.W.S. T.N. GILL Cruise 3							
29	July 29, 1953	31° 00'	79° 13.2'	1300	19	12.1	70 meter oblique plankton tow
30	July 29, 1953	30° 57'	79° 37'	1700	1-18	9.0-34.4	Surface plankton tow and dip net
U.S.F.W.S. T.N. GILL Cruise 4							
Tongue of the Ocean Sta. 1	Oct. 7, 1953	24° 37'	77° 18'	2000	T.O. 1	43.7	Dip net
University of Miami Marine Laboratory Collection							
N.G. 38	Jan. 14, 1952	25° 50'	79° 56'	2300	N.G. 38	71.2	"

TABLE 1. (Continued)

U.S.F.W.S. ALASKA Cruise LLI-2						
—	May 25, 1952	27° 19'	87° 30'	1012	A 4	26.9
—	May 30, 1952	26° 00'	85° 15'	0020	A 5	55.4
—	June 2, 1952	28° 00'	85° 00'	0600	A 2	8.2
						High Speed Plankton Sampler (surf.)
U.S.F.W.S. ALASKA Cruise 8-3C						
—	Feb. 25, 1953	25° 06'	87° 30'	1030	A 3	19.8
						15 meter horizontal plankton tow
U.S.F.W.S. ALASKA Cruise 11-3C						
—	June 9, 1953	26° 40'	87° 30'	0600	A 1	6.1
						High Speed Plankton Sampler (surf.)
W. L. Sweeny's M/V MUIR St. John, New Brunswick, Canada						
—	Sept. 17, 1953	42° 14'	66° 32'	—	N.S.	2768
						Harpoon
Commercial Fishing Vessels of Havana, Cuba						
—	Aug. or Sept.	Off Havana	—	—	C 1	1194
—	March 23 & 24, 1954	Florida Current, three miles offshore between the Almendares River and Guanabo Beach	—	—	C 2-C 10	1797-3073
						Long-line gear

In calibrating the micrometer eyepiece, a maximum error of one percent could have been induced when the millimeter equivalent was rounded off to hundredths, corresponding to whole unit designations on the eyepiece. When these millimeter readings for whole units on the eyepiece were rounded off to the nearest tenth of a millimeter, another one percent maximum error could have been induced because of visual limitations within the eyepiece field. Therefore it is reasonable to assume no greater error than two percent with respect to the size of the part in question.

In reference to the adult specimen measurements the above accuracy is not in effect. The measurements from specimen No. N.S. were obtained through the courtesy of Captain C. J. d'Entremont of Lower West Pubnico, Nova Scotia, and were given to the nearest inch. In addition, measurements of ten specimens were made to the nearest quarter inch by Mr. Jose A. Suarez, biologist with the "Centro De Investigaciones Pesqueras" Playa Habana, Bauta, Havana, Cuba. In converting these inch measurements to millimeters it was found that they are within the two percent maximum error and can be used adequately for comparisons when considering proportions of body parts.

Definitions. Standard Length: Tip of snout to distal margin of last hypural segment. In the smallest specimens where no hypurals were evident this measurement was terminated at the distal margin of the urostyle.

Total Length: Tip of snout to distal margin of longest caudal ray.

Body Length: Posterior margin of opercle to distal margin of last hypural segment or as in the case of the smallest specimens to the distal margin of the urostyle.

Mandible: Tip of lower jaw to posterior margin of the angle of the jaws.

Caudal Fin Length: Distal margin of the last hypural segment to the distal margin of the longest caudal ray or as in the case of the smallest specimens from the posterior margin of the urostyle to the distal margin of the longest caudal ray.

Depth at Peduncle: Depth of body taken vertically from the base of the last dorsal ray.

Depth of Snout: Depth taken vertically at the anterior margin of the eye to the distal edge of the premaxillary.

Head Depth: Represents greatest depth of the head.

All other measurements are standard accepted distances.

TABLE 2. MEASUREMENTS IN MM AND COUNTS

Specimen Number	AI	Reg.	73	A2	18	19	17	15	A3	8	9	11	16
Standard Length	6.1	7.8	8.2	8.2	9.0	12.1	14.5	18.2	19.8	20.2	20.4	20.7	20.8
Total Length	6.3	8.1	8.5	8.5	9.3	12.5	15.9	19.5	21.7	22.1	22.5	22.8	22.5
Body	3.0	4.5	4.4	4.4	4.3	6.7	6.9	9.8	9.4	10.7	10.2	10.7	10.3
Head	3.1	3.3	3.8	3.8	4.6	5.4	7.7	8.5	10.4	9.4	10.3	10.0	10.4
Snout	1.5	1.5	2.1	2.1	2.5	3.3	4.9	5.8	7.5	6.6	7.5	7.0	7.4
Mandible	2.4	2.2	2.7	2.7	3.4	3.8	5.3	6.1	7.7	6.7	7.4	7.5	6.1*
Maxillary	1.2	1.3	1.3	1.3	1.3	1.4	1.7	1.8	2.2	1.7	1.7	1.4	1.8
Postorbital	0.9	1.1	1.0	1.0	1.2	1.2	1.7	1.6	1.6	1.6	1.6	1.6	1.8
Caudal Fin Length	0.2	0.3	0.3	0.3	0.3	0.4	1.4	1.3	1.9	1.9	2.1	2.1	1.7
Snout to dorsal origin	2.9	3.4	3.8	3.8	5.1	5.6	7.8	8.5	10.7	9.5	10.0	9.8	10.1
Snout to anal origin	4.3	5.7	6.3	6.3	7.2	8.7	10.9	13.3	14.6	14.9	14.9	14.8	15.1
Snout to pectoral origin	3.2	3.2	3.8	3.8	4.9	5.4	7.3	8.9	10.5	9.9	10.2	9.8	10.2
Greatest Depth	0.8	1.2	1.5	1.5	1.9	1.9	2.3	2.9	1.8	2.6	2.4	2.4	2.3
Head Depth	1.1	1.4	1.4	1.4	1.9	1.9	2.3	2.9	2.3	2.6	2.3	2.4	2.3
Depth at anus	0.5	0.9	0.8	0.8	1.2	0.9	1.1	0.9	1.0	1.1	0.9	0.9	1.0
Depth at peduncle	0.3	0.4	0.4	0.4	0.4	0.5	0.6	0.7	0.6	0.6	0.6	0.6	0.6
(ant. margin)													
Depth of snout	0.6	0.7	0.8	0.8	0.8	0.9	1.2	1.4	1.0	1.1	1.4	1.3	1.2
(post. margin)													
Eye diameter	0.7	0.7	0.7	0.7	0.8	0.9	1.1	1.2	1.2	1.2	1.2	1.3	1.2
Dorsal base	2.2	3.4	3.3	3.3	3.0	5.3	6.8*	8.4	9.2	9.7	9.9	9.1	8.5
Anal base	0.9	1.2	0.9	0.9	0.9	1.7	4.6	3.1	3.3	3.7	3.4	3.4	3.2
Pectoral base	0.3	0.5	0.4	0.4	0.6	0.8	0.8	0.8	0.8	0.9	0.8	0.8	0.8
Dorsal rays (number)	—	—	—	—	—	—	43	45	43*	46	48*	46	42*
Anal rays (number)	—	—	—	—	—	—	16	17	18	17	17	17	17
Pectoral rays (number)	—	—	—	—	—	—	17	15*	16	16	16	16	15*

*uncertain measurement or count

TABLE 2. (Continued)

Specimen Number	6	12	13	5	7	10	14	A4	4	3	Reg. 61	2
Standard Length	21.2	21.9	22.1	22.1	24.8	25.8	25.8	26.9	27.2	28.0	28.6	28.7
Total Length	23.1	23.8	24.0	24.0	26.3	27.9	28.1	29.3	29.9	30.1	31.2	31.2
Body	10.6	11.3	11.5	11.6	13.1	13.8	13.2	13.6	14.0	15.4	14.7	14.7
Head	10.7	10.9	10.5	10.2	11.6	12.0	12.4	13.3	13.4	13.0	14.4	13.9
Snout	7.8	7.9	7.5	7.4	8.7	9.1	9.0	9.9	9.9	9.2	10.6	10.4
Mandible	7.8	8.0	7.7	7.9	8.1	9.3	9.1	9.9	9.9	9.1	10.8	10.1
Maxillary	2.1	2.0	1.9	2.2	2.1	2.4	2.4	2.3	2.4	2.4	2.8	2.3
Postorbital	1.9	1.5	1.8	1.8	1.6	2.1	2.1	2.0	2.1	2.1	2.3	2.3
Caudal Fin Length	1.9	1.9	1.9	1.9	1.5	2.1	2.3	2.4	2.7	2.1	2.6	2.5
Snout to Dorsal origin	10.5	10.7	10.6	10.3	11.5	12.3	12.2	13.1	13.0	12.8	14.6	14.0
Snout to Anal origin	16.1	16.5	15.6	16.0	17.0	19.9	20.7*	20.5	19.8	21.0	21.1	21.9
Snout to Pectoral origin	10.9	10.8	10.5	10.3	11.5	12.5	12.6	13.1	13.2	13.0	14.0	14.1
Greatest Depth	2.5	2.8	2.4	2.6	2.9	2.6	2.6	2.2	2.8	2.8	2.6	2.8
Head Depth	2.3	2.3	2.4	2.4	2.4	2.6	2.6	2.6	2.5	2.8	2.5	2.8
Depth at Anus	0.9	1.4	1.0	1.1	1.1	1.3	1.2	1.1	1.3	1.3	1.3	1.4
Depth at Peduncle (ant. margin)	0.6	0.7	0.6	0.6	0.8	0.8	0.8	0.6	0.9	0.9	0.9	1.0
Depth of Snout (post. margin)	1.3	1.4	1.1	1.5	1.6	1.5	1.4	1.3	1.4	1.4	1.5	1.4
Eye diameter	1.3	1.1	1.3	1.3	1.3	1.4	1.3	1.4	1.3	1.3	1.4	1.5
Dorsal base	10.0	10.5	10.3	10.9	11.3	12.0	11.8*	13.9	12.9	14.0	14.1	13.5
Anal base	3.7	3.7	3.6	4.2	3.9	4.4	4.6	4.6	5.5	5.1	4.8	5.1
Pectoral base	0.8	0.7	0.7	0.9	0.9	0.9	0.7	0.6	0.8	0.9	0.9	0.8
Dorsal rays (number)	46	45	44	40*	47	46*	46	45*	44	48	46	41
Anal rays (number)	17	17	17	17	17	17	17	17	17	18	17	17
Pectoral rays (number)	16	17	17	15*	17	17	16	16	17	17	17	17

*uncertain measurement or count

TABLE 2. (Continued)

Specimen No.	Reg. 39	I	T.O.I	A5	Reg. 17	Reg. 53	N.G. 38	Reg. 72	S.C.	C1	C2	C3
Standard Length	33.0	34.4	43.7	55.4	68.8	70.0	71.2	72.5	192.1	1194	1797	1905
Total Length	36.1	37.8	47.6	60.4	76.1	76.8	78.1	80.9	215.2	1359	2007	2235
Body	18.0	17.2	23.7	29.1	38.8	38.3	39.4	39.6	111.7	597	857	908
Head	15.3	16.8	20.4	26.4	30.9	31.9	32.3	32.8	79.9	597	940	997
Snout	11.2	12.8	15.7	20.3	24.0	24.9	25.4	25.9	61.4	445	686	787
Mandible	12.4	12.1	15.2*	19.0	22.9	23.3	—	24.0	51.0	178	229	222
Maxillary	2.8	3.1	3.2	3.8	4.9	4.2	4.9	4.8	10.0	—	—	—
Postorbital	2.3	2.3	2.9	3.8	4.1	4.5	4.5	4.5	12.2	120	197	146
Caudal Fin Length	3.1	3.4	3.9	5.0	6.3	6.8	6.9	8.4	23.1	165	210	330
Snout to Dorsal origin	14.1	17.0	20.1	25.5	30.1	31.1	31.6	32.5	77.4	—	—	—
Snout to Anal origin	24.3	25.5	31.7	40.7	49.0	49.4	52.2	53.2	136.4	—	—	—
Snout to Pectoral origin	14.0	16.9	19.8	26.1	30.5	31.2	32.5	33.0	79.8	—	—	—
Greatest Depth	3.4	2.8	3.6	3.3	5.0	5.3	5.3	5.0	12.9	—	—	—
Head Depth	2.9	2.8	3.8	3.8	5.0	4.8	5.6	5.0	12.0	—	—	—
Depth at Anus	1.4	1.4	1.2	1.9	2.6	2.8	2.9	2.9	9.0	—	—	—
Depth at Peduncle (ant. margin)	1.0	1.0	1.1	1.1	1.8	1.7	1.8	1.7	5.3	—	—	—
Depth of Snout (post. margin)	1.8	1.7	1.8	1.9	2.5	2.6	2.4	2.7	6.5	—	—	—
Eye diameter	1.6	1.7	1.8	2.2	3.0	2.9	2.8	2.9	6.1	32	57	64
Dorsal base	16.6	16.3	22.1	25.8	32.9	34.3	34.8	35.4	97.0	—	—	—
Anal base	6.5	6.2	7.8	9.8	12.2	14.1	12.0	13.8	33.0	—	—	—
Pectoral base	1.1	1.0	1.3	1.4	1.7	2.0	2.0	1.8	5.0	—	—	—
Dorsal rays (number)	47	47	47	48	48	44	44	45	48	—	—	—
Anal rays (number)	18	18	17	17	17	17	17	17	17	—	—	—
Pectoral rays (number)	17	16	17	16	18	16	16	17	16	—	—	—
Weight in lbs.	—	—	—	—	—	—	—	—	—	12	75	90

* uncertain measurement or count

TABLE 2. (Continued)

Specimen Number	C4	G.&C., 1937	C5	G.&C., 1937	C6	N.S.	C7	C8	C9	C10	G.&C., 1937
Standard Length	2057	2553	2629	2692	2692	2768	2769	2794	3035	3073	3607
Total Length	2311	—	3023	—	2997	3276	3073	3086	3556	3366	—
Body	1029	1232	1295	1308	1359	1346	1372	1410	1537	1524	1753
Head	1029	1321	1334	1384	1334	1397	1397	1384	1497	1549	1854
Snout	826	991	984	1029	984	1067	1048	1067	1130	1175	1397
Mandible	210	241	267	—	267	279	279	254	311	292	343
Maxillary	—	—	—	—	—	—	—	—	—	—	—
Postorbital	139	254	255	279	267	254	266	241	278	285	356
Caudal Fin Length	254	—	394	—	305	508	304	292	521	293	—
Snout to Dorsal origin	—	—	—	—	—	—	—	—	—	—	—
Snout to Anal origin	—	—	—	—	—	—	—	—	—	—	—
Snout to Pectoral origin	—	—	—	—	—	—	—	—	—	—	—
Greatest Depth	—	—	—	—	—	—	—	—	—	—	—
Head Depth	—	—	—	—	—	457	—	—	—	—	—
Depth at Anus	—	—	—	—	—	—	—	—	—	—	—
Depth at Peduncle	—	—	—	—	—	—	—	—	—	—	—
Depth at Peduncle (ant. margin)	—	—	—	—	—	101	—	—	—	—	—
Depth of Snout (post. margin)	—	—	—	—	—	—	—	—	—	—	—
Eye diameter	64	76	95	76	83	76	83	76	89	89	102
Dorsal base	—	—	—	—	—	—	—	—	—	—	—
Anal base	—	—	—	—	—	—	—	—	—	—	—
Pectoral base	—	—	—	—	—	—	—	—	—	—	—
Dorsal rays (number)	—	—	—	—	—	—	—	—	—	—	—
Anal rays (number)	—	—	—	—	—	—	—	—	—	—	—
Pectoral rays (number)	—	—	—	—	—	—	—	—	—	—	—
Weight in lbs.	100	225	230	—	225	212	210	220	325	375	601

LIVE COLOR OBSERVATIONS

The following is a color description made while the specimen was swimming in a tank of seawater in the laboratory of the vessel only minutes after capture. The specimen was kept alive for about one hour and there was no change from this pattern until after death when the specimen had been preserved. This specimen came from station 17 on cruise 2.

The over-all color of the dorsal surface of this specimen was royal blue marked alternately with seven vertical bands of light blue from the head to the caudal fin (Figure 9). The bands were not uniform in width and did not become silver until the ventral-most one-fifth of the lateral aspect was reached. The first band was located behind the head and the last band reached from midway on the caudal peduncle onto the caudal fin. The lower edge of the anal was hyaline, as was the posterior edge of the dorsal. Both tips of the caudal were also hyaline and the pectoral showed no color. The distal one-fourth of the premaxillary was white, and the extreme tip of the mandible lacked color. In profile only the extreme edge of the ventral aspect was silver, continuing from the tip of the mandible all the way to the caudal base. The dorsal fin was dark blue (almost black) with light blue areas corresponding to the light bars on the body. The anal fin lacked any carryover of pigment. There was a dark blue bar running obliquely from the gape (ahead of the angle of the mouth) through the middle of the eye and was lost about three-fourths of the way across the opercle. (Not shown on Figure 9, but is similar to that shown on Figure 10).

DESCRIPTION OF SPECIMENS

Specimen No. A1—6.1 mm. The pigmentation of this specimen is restricted to the snout, cranial region and the lateral midline of the body. The snout is darkest, with the area around the pectoral fin origin and a vertical bar just posterior to the anal region being next darkest. There are a few chromatophores present on the dorsal surface of the urostyle and three on the ventral surface.

The head is characterized by the snout and mandible terminating in the same plane, and an eye that is lobed with the constrictions present on the dorsal and ventral sides. The preorbital ridge contains one developed spine with a hump anterior to it. The supraorbital ridge contains five spines and connects with the single cranial spine. This connection is represented by a thickened area present under the skin.

The osseous membranes of these two groups of spines do not connect. One temporal spine is present. The preopercular margin has two short slender spines and two long slender spines, the latter crossing the opercular margin. There is one spine at the angle of the jaws. The nostril is large and single, with the area around it appearing as a large depression. The tip of the snout contains one hooked tooth pointed upward on each side. Eleven teeth are present on the premaxillary with several more in the skin tissue at the angle. The mandible has twelve teeth, with several additional teeth present in the skin tissue at the angle. The distal teeth are small, slender and hooked while the rest are more knife-like. The dorsal margin of the opercle is on a plane running horizontally backward from the top of the eye. The eye is large being contained 8.7 in the standard length.

The body is characterized by lack of pigment on the dorsal surface, and the fin fold condition of the median fins. A thinning portion of the fold indicates the dorsal and anal insertions. There are no ray bases in evidence. The urostyle points straight back and the fin fold at the caudal is shortest at the tip of the urostyle. The fin fold progresses forward from the anus to about halfway to the pectoral insertion. The pectoral fin is short with its base high on the body. While rays are not evident in any of the fin membranes, some small supporting elements can be seen.

Specimen No. Reg. 73—7.8 mm. Only scattered chromatophores are present on the dorsal side of the snout, the cranium, and the dorsal two-thirds of the body caudally to the dorsal and anal insertions. The mandible lacks pigmentation as do the fin folds, the pectoral fin, and the ventral third of the body (Figure 2).

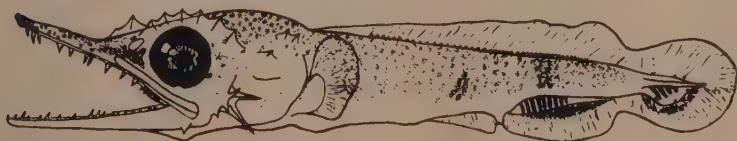


FIGURE 2. 7.8 mm, specimen No. Reg. 73.

The fins are not developed, but there are traces of supporting elements throughout the fins. Some of the dorsal, anal and caudal ray bases are evident under the skin. There is no full separation of the fins, but the terminations of the dorsal and anal bases can be noted by a thinning of the fold. The fin fold is continuous from just above the

opercular margin to the anus, where it is interrupted by the anal aperture and continues a short way forward of the aperture. The pectoral fin is high on the body and is slightly more fan-shaped than the later stages.

The head is characterized by spination consisting of a preorbital ridge of two spines, a supraorbital ridge with six spines, one temporal spine and two cranial spines. The preopercle contains three small spines, and two large spines that cross the opercle. There is one spine at the angle of the jaw. The snout is fairly short in proportion, with the premaxillary containing fifteen knife-like teeth directed downward. There are three hooked teeth at the tip of the premaxillary that point up and forward. The five teeth closest to the angle of the jaws are enveloped in skin tissue and are not fully developed. The mandible contains eighteen similar teeth with the seven teeth closest to the angle of the jaws contained in skin tissue. The nostril is single, forming a large pit. The eye is fairly large being contained 11.1 in the standard length. The maxillary is large at this size.

The body is characterized by light chromatophore distribution and is rather elongate; this giving rise to the supposition that the specimen is in the process of transforming from the finfold stage into a juvenile. There are no spines on the body. The urostyle is long and pointed straight back. The ventral surface of the urostyle shows four caudal fin ray bases imbedded in skin tissue, but no rays. Pigmentation is light with chromatophores present on the dorsal two-thirds of the body. The darkest areas are over the center of the anal base and just forward of the anus on the lateral midline of the body. The anus is positioned about two-thirds the way back on the body and is in an extended condition.

Subcutaneous pigmentation is evident on the opercular apparatus and to a large extent on the lateral midline of the body. There is a purple stain in the body cavity just prior to the anus, probably due to food organisms in the gut.

Specimen No. 18—9.0 mm. This specimen is the typical light tan of preserved material, with some darker pigmented areas on the body. The ventral surface of the fish is white (Figure 3).

No counts of the fin elements are available since the fins are not yet fully developed. The pectorals are rather high on the body lying just below the main axis of the fish with the ventral most rays the least developed and that portion of the fin being hyaline.



FIGURE 3. 9.0 mm, specimen No. 18

The head at this stage is characterized by a large eye (11.3 in the standard length), scattered chromatophores on the cranial region, a single nostril, a high supraorbital ridge with heavy spines running posteriorly to the edge of the preopercle, two strong spines crossing the opercle, four smaller spines on the preopercle, three spines at angle of jaw, and a snout that is a little longer than the mandible. Also two cranial spines and one temporal spine are present. The premaxillaries are toothed with 18 rather strong knife-like teeth which interfit fairly regularly with the mandibular teeth, of which there are 17. The slender maxillary reaches from the angle of the jaws to a vertical line under the nostril.

The body at this size is rather short and stumpy with the characteristic four rows of keeled spines typical of later stages being absent. Only a portion of one of these rows is present and it takes the form of a row of single spines on the ventral surface either side of the ventral midline. They begin just anterior to the longest rays of the pectoral and end just posterior of the anus. The body cavity is long with the anus taking a position in the posterior one-third of the body. The anal fin is past its finfold stage with most of the elements present. The dorsal fin is not in the same advanced stage of development and the anterior portion of the fin is hyaline. On the posterior two-thirds of the fin supporting structures can be seen. The caudal fin is more fully developed, in a slightly heterocercal condition, with the greatest area of development being the ventral rays. Pigmentation on the body is confined to small chromatophores on the dorsal surface which are darkest and largest on the median axis of the body. There are two areas of light blue pigment near the anus seeming to come from some structure within the body cavity. This could be staining of the gut due to food organisms in the process of digestion.

Specimen No. 19—12.1 mm. The color faded during preservation and like the 9.0 mm. specimen appears light tan with scattered dark chromatophores. A hint of the barring pattern of larger specimens is

evidenced here by chromatophore concentrations, especially on the posterior half of the fish. The cranium has the characteristic spotted pattern of earlier stages and the snout is becoming more heavily pigmented. The mandible shows greater aggregations of chromatophores as does preopercle and the opercle. The belly is white as is the tip of the snout and the under surface of the mandible (Figure 4).

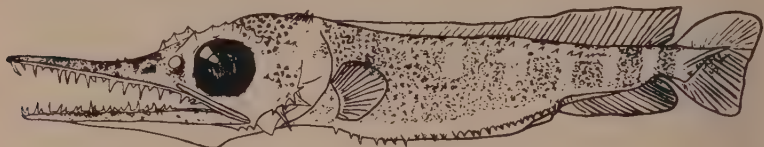


FIGURE 4. 12.1 mm, specimen No. 19.

No positive counts of the fin elements can be made as they are not fully developed at this stage. The position of the pectorals is still high.

The head is now characterized by much denser pigmentation and the presence of two distinct spines on the snout. The nostril remains as a single opening but its size has increased considerably. The upper jaw contains 21 teeth that are larger than at the 9.0 mm stage. The mandible contains 22 teeth which have also enlarged. The eye has decreased in proportional size (13.4 in the standard length) and the orbital bones are much more evident. The preopercle contains four small spines, two large spines (as in the smaller specimen), but more chromatophores than the previous stage. The three spines at the angle of the jaws are still in evidence, the cranial spines number three instead of two, and the temporal spines number two instead of one.

The body has elongated slightly. There are two rows of keeled spines with the ventral row the stronger, originating under the pectoral insertion and extending to just over the anus. The dorsal row begins at the top of the opercle, extends to a vertical line about midway of the anal base and is strongest anteriorly. The caudal fin is slightly more heterocercal with the distal end of the vertebral column turning upward at a greater angle.

The ventral caudal rays have developed more than at the previous stage. The anal fin has rays in an early stage of development, and the incomplete rays number 15. The posterior portion of the dorsal fin is fairly well developed with rays in a filamentous stage. The anterior one-fifth of the fin lacks supporting elements, and is very low. There is evidence of subcutaneous pigmentation all over the body, espe-

cially in the opercular region. The body cavity contains four dark spots near the anus, probably due to food organisms in the gut.

Specimen No. 17—14.5 mm. At this size the pigmentation is much heavier than the earlier stages described, and the barring pattern is evident. The mandible has darker pigmentation than the smaller specimens and the snout shows larger areas of dark pigmentation. A portion of the skin on the distal end of the snout has been torn away thus giving the effect of light chromatophore distribution. The cranial and opercular regions show denser pigmentation than in previous stages (Figure 5).



FIGURE 5. 14.5 mm, specimen No. 17.

The fin elements are fully developed at this size and the dorsal fin contains 43 elements with only the posterior-most being discerned as rays. The anal contains 16 elements and the pectoral contains 17 elements. The position of the pectoral fins is relatively the same as in earlier stages.

The head is characterized by even denser pigmentation than the previous specimen. Spination on the snout is developing rapidly and consists of four heavy spines. The nostril has almost completely split, a small flap of skin remaining between the two apertures. The upper jaw contains 25 teeth, which appear reduced in size. The mandible contains 29 teeth, which likewise appear smaller than in the previous specimen. The smallest of these mandibular teeth appear needle-like instead of the heretofore knife-like appearance. The eye is about the same proportion (13.2 in the standard length). Orbital bones are evident. The preopercle contains four small spines and two large spines. The angle of the jaw has four spines instead of three heretofore. The preorbital ridge now contains four spines, the temporal spines number three instead of two, and the cranial spines number four instead of three, as in the previous specimen. The snout now has four large spines with the anterior most three beginning to group into a pattern; probably a row. The supraorbital ridge has seven spines, but there is doubt as to the validity of the count because the ridge is broken in two places.

The body has not elongated to any extent, although the depth in

the belly region has decreased, giving the effect of general elongation. The stomach of the previous specimen was full while the stomach of this specimen appears empty thus giving rise to this apparent depth decrease. The dorsal row of keeled spines now reaches from the hind margin of the opercle to the caudal peduncle, and the spines are grouped into two's and three's, with a membranous structure connecting the spines. The ventral row of spines has developed likewise and extends from the hind margin of the pectoral base to the caudal peduncle. At this stage a second dorsal ridge has formed and contains small singular spines. This ridge extends from under the 9th dorsal element to the caudal peduncle with the spines becoming smaller distally. A second ventral ridge has also formed and it extends from under the 13th dorsal element to over the 6th anal element. Like the second dorsal ridge these spines are small and needle-like and are not connected. The caudal fin is still heterocercal, with the hypural segments undifferentiated, but the distal end of the vertebral column has taken on a much steeper dorsal angle. The caudal rays on the axis of the body and ventrally are fully developed while the dorsal rays can be seen as very fine supporting structures without the characteristics of true rays. The anal fin is fully developed with 16 elements. The anterior most elements are undifferentiated and cannot be separated into true rays. The dorsal fin is fully developed with 43 elements. As in the anal, the anterior most elements cannot be differentiated into true rays. There is still a small hyaline area on the anterior portion of the dorsal fin. The pectoral fin is fully developed with 17 elements. All of these elements with the exception of the four ventral most ones are branched at tips. Subcutaneous pigmentation is present in the body cavity, but the nature of this cannot be determined.

Specimen No. 15—18.2 mm. The original color of this specimen has faded, but the characteristic pigment spots remain. The intensity of the pigment spots has increased, giving the fish much more color. The snout is heavily pigmented, being the darkest area on the specimen. The mandible is also heavily pigmented, with the chromatophores running together and forming dense areas. The cranial region has darkened, with the pigment spots forming large circles with dense centers, and the radii of the chromatophores are almost invisible. The subcutaneous pigmentation on the opercular apparatus is more frequent as well as darkened. For the first time there is considerable pigmentation on the interorbital area. The body proper shows a vivid barring pattern of four distinct bars. The pigmentation of these

barred areas merge over the dorsal fin base, with a large amount of pigment being distributed on the interradi al membrane. The posterior three bars indicate this, with the anterior most bar represented by a few pigment spots. The posterior most bar has extended onto the anal fin and is represented by a few pigment spots on the interradi al membrane of the last three rays. The chromatophores in the region of the gut are similar to those of the opercular region, but are slightly denser. These chromatophores are larger and are of the same nature as the subcutaneous chromatophores that appear on the dorsal surface of the body cavity. There is a large dark blueish area within the gut which can be discerned as the eye of a fish that has been partially digested.

The head is characterized by heavier pigmentation and more numerous spines. The snout now has one row of keeled spines that runs along the edge of the premaxillary, and another row that runs on either side of the dorsal midline. These latter spines are in groups of three and are connected by bony-like partitions. The preorbital ridge of spines number five, as against four at 14.5 mm. The number of spines at the angle of the jaw has increased to five, but the rest of the head spines are the same as the previous specimen. The upper jaw contains 32 teeth which are much smaller in comparison to the teeth of the previous specimen. The majority of these teeth appear knife-like. The mandible contains 39 teeth that are smaller than the premaxillary teeth. In several instances these mandibular teeth have grown side by side instead of in a row. The nostril resembles very much the same structure and condition that prevailed in the 14.5 mm stage. The eye has decreased in proportion, being contained 15.2 in the standard length.

The body has slightly elongated. With the food organisms present in the gut, this region is distended and gives the appearance of the depth having increased. The dorsal and ventral rows of keeled spines are now complete, and the spines are arranged in groups of twos, with a bony partition connecting the spines. The dorsal row extends from the margin of the opercle to the caudal peduncle, and the ventral row extends from the pectoral insertion to the caudal peduncle, both ending in the same plane. The second dorsal row begins under the 12th dorsal element and continues posteriorly ending under the 41st dorsal element. Another dorsal row begins at the margin of the opercle and extends a little way past the beginning of the second dorsal row, thus giving the latter the appearance of breaking at this

point, under the 12th element. However, the body in general is covered with minute singular spines, while the rows contain double spines plus a connecting partition. The second ventral row originates at the pectoral base and extends posteriorly ending over the 12th anal element. The posterior most spines are single, while the anterior spines are double and have connecting partitions. The caudal fin is still in a heterocercal condition with the hypural segments undifferentiated. The ventral rays are fully developed, while the dorsal rays can be seen as small supporting structures. The dorsal fin is complete, with only a very small hyaline area prior to the first element. The pigmentation of the interradi al membrane has been discussed above. The dorsal elements number 45, with only the posterior ones discernible as rays. The anal contains 17 elements and, like the dorsal, only the posterior ones are discernible as rays. The pectoral fin is fully developed and contains 15 elements. However, the ventral portions of both fins are damaged so that count is not positive.

Specimen No. 8—20.2 mm. At this stage (Figure 6) the pigmentation has increased considerably and in some areas is so dense as to give an almost black appearance. The snout has the areas of heaviest pigmentation. The skin is intact on the entire snout and pigmentation is evident to the tip. The mandible is also dark and like the snout the chromatophores extend to its tip. The cranial region is still dark and at this size there is, for the first time, heavy color distribution on the opercular apparatus, the preopercle bearing the heaviest pattern. The interorbital area is entirely pigmented, and in this respect resembles the posterior portion of the snout and the cranial region. The body is more heavily pigmented, with large dark areas present along the lateral midline of the body. These are not quite as dense as they should be on the drawing because for purposes of illustration of the keeled rows the pigmentation had to be lightened. The barred pattern on the body is plainly evident as five pigmented bars extending from the dorsal base to the dorsal outline of the body cavity in the mid-body region, and all the way to the anal fin base in the posterior body region. The previous specimen had only four such bars. Four bars on the present specimen are represented by pigmented areas on the dorsal interradi al membrane and the fifth, or posterior most bar, is carried onto the interradi al membrane of the anal fin. The caudal peduncle is more heavily pigmented, and for the first time a large pigmented area appears on the caudal fin. As yet the pectoral is without chromatophores. Subcutaneous pigmentation on the opercular



FIGURE 6. 20.2 mm, specimen No. 8.

apparatus and on the dorsal surface of the body cavity is quite heavy.

The head has undergone considerable change from the previous size. The snout has two rows of keeled spines that are larger and more numerous. These spines are in groups of two and extend half-way to the tip. At the anterior most point of these rows several very small spines can be seen, indicating that the spination of the snout is not complete. The preorbital ridge and the supraorbital ridge have become larger and stronger, but the number of spines remains the same. The latter runs farther back on the temporal bone. The preopercle still has four small spines and two large spines. The four small preopercular spines have increased their area considerably, almost giving the preopercle a serrate appearance. The keeled row of spines at the angle of the jaws still numbers four spines, but there has been anterior development of this row, giving rise to six smaller spines on the ventral portion of the lower jaw. The teeth on the lower jaw have increased to 41 and have considerably decreased in size. In several places there seem to be two teeth side by side instead of in series, but there are not enough of these to indicate a double row of teeth. The upper jaw teeth number 32 and have likewise decreased in size. These are in a definite single row, do not continue to the tip of the premaxillary as in the previous stages, and end just beyond the tip of the mandible. The nostril appears to have completed its division at this stage, but the skin flap is still present, covering most of the anterior nare. The eye is smaller in proportion, being contained 16.8 in the standard length. The orbital bones are becoming less evident.

The body has elongated and the anus seems to be in a more anterior position. The rows of keeled spines are almost completed, with the dorsal and ventral rows composed of rather heavy spines joined by a bony partition. They are still present in groups of twos, with one long spine and one short. The dorsal row extends onto the caudal peduncle, but the ventral row ends at the posterior margin of the anal fin. The second dorsal row originates under the 10th dorsal ray and ends under the 43rd ray. These spines are smaller,

but the anterior-most ones are large, indicating that their size might increase. The second ventral row ends over the 15th anal ray and is rather vague in its origin. Just anterior to the anus there are several other groups of spines that tend to obscure the beginning point of this row. Around the lateral midline of the body numerous spines have grouped and formed keeled plates while others still remain single, giving the whole body a generally rough appearance. The dorsal fin is complete and has 46 elements. The anterior portion is still relatively low but its degree of rise is increasing. There are four pigmented areas that correspond directly to the bars on the body. The anal fin is complete and contains 17 rays. All but the first two elements split distally, thus making ray identification possible. There is one area of pigmentation on the anal fin, on the interradi al membrane between the last five rays and it is present only on the distal edge of the membrane. The caudal fin has developed almost fully, with the urostyle just faintly recognizable. No rays are present anterior to the urostyle. The pigmentation of the caudal fin is restricted to the membrane joining the median rays and does not extend any distance onto the fin. The pectoral fin is showing development toward its ultimate shape and has 16 rays. There is no pigmentation on the fin, but the fin base shows scattered chromatophores.

Specimen No. 6—21.2 mm. The general pigmentation of this specimen is heavier than at the previous size. The snout and mandible remain the darkest areas on the head, with the interorbital area showing an intergradation between these two dark areas. The dorsal surface of the peritoneal cavity is represented by a black band along the body cavity wall, which gives the appearance of a heavy median lateral area of pigmentation. The barring pattern is in evidence, with five bars apparent. The anterior four of these bars are represented by pigmentation on the interradi al membrane of the dorsal fin, and further, the fourth bar posteriorly is represented by like pigmentation on the posterior rays of the anal (very similar to the 20.2 mm specimen). The ventral surface lacks pigmentation except for scattered chromatophores at the isthmus and on the caudal peduncle.

The head remains essentially the same as the previous specimen. The snout spines have become more numerous, the preorbital ridge now contains six spines, and the row of spines at the angle of the jaws now numbers six. The anterior portion of the row of spines at the jaw angle has split off and formed a row of keeled spines similar to those on the snout; they are in groups of two, one long

and one short with a connecting partition. There are five preopercular spines, more regularly spaced than previously. These almost connect with the row of spines that are present at the angle of the jaw. The two large preopercular spines have become heavier than before. The eye remains essentially the same, being contained 16.3 in the standard length. The nostril is double but the tube is not completed; the skin flap is still present and directed forward over the anterior nare.

The body shows no essential changes compared with the previous specimen. The dorsal and ventral rows of keeled spines now extend onto the caudal peduncle and in doing so are directed medially, almost giving the appearance of two lateral caudal keels. These spines are still in groups of two but the bases have become further ossified, thus giving the appearance that they compose a keel-like structure. The second dorsal row now extends to about the 10th or 12th dorsal ray anteriorly and almost onto the caudal peduncle posteriorly. The second ventral row does not go quite as far posteriorly and becomes vague in its origin just forward of the anus. The lateral portions of the body are now literally covered with spines in groups of two, and have small singular spines spaced in between, making the body appear very rough. All of the fins have completed development and the rays are in evidence. The pectoral base has moved slightly downward although it is by no means in its final position. The urostyle can no longer be discerned.

Specimen No.7—24.8 mm. At this size there have been no major changes in either the head or the body. The pigment distribution is essentially the same, with the dorsal portion of the peritoneal cavity still visible as a dark band. The bar pattern is the same, with the fifth bar becoming much more evident; the position of this bar is on the caudal peduncle and its posterior margin is on the interradi al membrane of the caudal fin.

The head remains about the same with only the spination changing. The snout contains two lateral rows of keeled spines and one median row. Anteriorly the lowest lateral row extends about half way to the tip and is composed of single spines. The mandible has a row similar to this latter row, which extends a little further anteriorly. The preopercular spines are unchanged. The eye has decreased somewhat, being 19.1 in the standard length.

The body remains approximately the same, except for the rows of keeled spines. At about the midpoint of the body the spines are in groups of three in the dorsal and ventral rows. The dorsal row re-

mains in groups of three for only about ten groups, but the ventral row groups of three start at the vertical midline of the body cavity and extend back past the anal fin origin. Both rows extend onto the caudal peduncle and turn medially, as before. The second dorsal row is now close to the main dorsal row, originating under about the 10th or 11th dorsal ray and extending posteriorly to just under the dorsal insertion. The second ventral row extends posteriorly to about the same place, but its origin becomes confused just anterior to the anus. At this stage several additional medial rows are in evidence and give the whole body a ridged appearance. Six rows are present, with many singular groups of spines scattered in between. In addition the pectoral fin base has developed a few scattered spines that give it a granular appearance. At the top of the opercular margin there have developed two heavy spines. Also, for the first time there are small singular spines on the surface of the preopercle, opercle and subopercle. The preopercular spines form a tilted "V"-shaped structure with the apex pointing toward the pectoral base and cradling the eye in the tip of the "V". The lower arm of the "V" extends onto the maxillary. The opercular and subopercular spines form no pattern.

Specimen No. 4—27.2 mm. There has been no overall change in appearance except for the spinous condition of the body and head. The pigmentation has become heavier in the principal areas: head, snout, mandible, dorsal peritoneal wall and lateral midline of the body. The interradi al membrane of all fins except the pectoral have denser pigment distribution, but the area covered is about the same. Denser areas are now present in the temporal and opercular regions. The barring pattern remains the same as the 21.2 mm specimen except the caudal bar which is heavier (Figure 7).

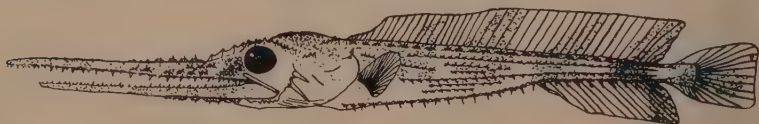


FIGURE 7. 27.2 mm, specimen No. 4

There has been no appreciable proportional change in the head. The snout is quite heavily spined, with one median dorsal row and two lateral rows. All of the spines are in groups of two and have a connecting partition. These rows extend about halfway to the tip of the snout. The mandible has two rows of spines that are also in groups of two, but these no longer extend beyond the spination of the snout.

The "V"-shaped row of singular spines is still present on the preopercle with the lower arm extending onto the maxillary. The five small spines on the margin of the preopercle have spread out in area, are almost equal in distance from each other, and give the margin a serrate appearance. The lower margin of this row now connects with the row of spines at the angle of the lower jaw. The two large preopercular spines are still present. The preorbital ridge is somewhat larger, but still contains six spines. The serrations of the supra-orbital ridge have become more densely spaced. The two spines at the dorsal margin of the opercle have become stronger but the position remains the same. The upper jaw now contains 43 teeth with little change in proportional size. For the first time a pattern is evident, as they appear to be grouping into a large and a small tooth alternately. This pattern is lost at both ends of the jaw, but in the middle two-thirds it is quite evident. The lower jaw now contains 51 teeth and is without the above pattern, except for a hint in the central portion. The eye is contained 20.9 in the standard length.

The spination on the body has become stronger at this size, with the dorsal keeled row composed entirely of groups of three spines (except on the caudal peduncle), with connecting partitions. The bases of these keeled spines have strongly ossified and give the appearance of little humps running under the individual groups of spines. The ventral row is in the same condition except that the anterior-most groups are made up of only two spines. Both of these rows extend onto the caudal peduncle as small singular spines and turn medially. The second dorsal row still originates under the 10th or 11th dorsal ray and extends back to the dorsal insertion. This row is composed of groups of two spines with connecting partitions and their bases have not ossified to the extent of the above two rows. The second ventral row is in the same condition, except for the first time the row is continuous past the anus anteriorly, and is not confused with the other scattered groups of spines in this area, a condition which prevailed in earlier stages. This row extends posteriorly to a point just over the anal insertion. Two short rows of small spines in the region of the body cavity run between the first and second ventral rows. Two similar rows run between the second ventral and second dorsal in the same region, giving the appearance of eight rows of spines on the body.

The fins have further developed with both the dorsal and anal increasing in height. Rays can be discerned in all fins except the first

five elements of the dorsal. They all are unsegmented, but are branched at their tips.

Specimen No. Reg. 39—33.0 mm. There has been little change except for the spination and the much denser pigmentation over most of the body. The same areas are still the darkest but in almost all areas the chromatophores are no longer distinguishable as separate pigment spots. The dorsal fin membrane has become much darker and there are now five dense areas with only slight pigment distribution in between. The caudal fin has denser pigmentation which is largely deposited on the ventral surface of the median rays giving the appearance of lines extending almost to the tip of the fin. The barring pattern of the body is still the same although now more evident than previously. No pigment is present on the pectoral fin (Figure 8).

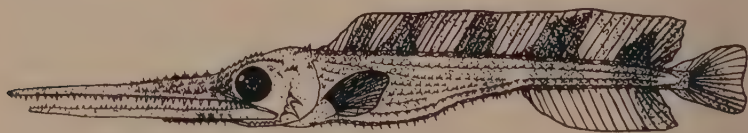


FIGURE 8. 33.0 mm, specimen No. Reg. 39.

The spination on the head has further developed with the two lateral rows on the snout being composed of heavy keeled spines in groups of two. The median and the lower lateral rows extend about halfway to the tip. The mandibular rows of spines have likewise become composed of groups of two for their entire length, and extend about halfway to the tip. The preopercular ridge connects at the angle of the jaw with the angular ridge of spines. The preopercular spines make its margin look serrate. The two large preopercular spines have become shorter and stouter. The preorbital ridge extends farther back on the head and now contains eight instead of six spines. The supra-orbital is little changed. The previous two spines at the dorsal margin of the opercle are now two groups of two heavy spines. The eye remains essentially the same being contained 20.6 in the standard length.

The spination on the body is relatively the same, except that the continuous second ventral row has become confused again. Just anterior to the anus it seems to split into an upper and lower branch, thus forming a "Y"-shaped ridge. The second row turns upward under the 10th dorsal ray and almost merges with the first dorsal row. For the

first time both of these secondary rows extend onto the caudal peduncle. In addition to the four very prominent rows from the anus posteriorly, there is also a small row of spines exactly on the lateral midline, making a total of five rows in this region. Small spines are in evidence all over the body, and especially on the head.

All of the fin rays are in evidence, except for the first three dorsal elements which are still unbranched.

Specimen No. A5—55.4 mm. Between 33.0 mm and the present specimen there was one specimen at 43.7 mm. There seemed to be no overall changes at that size which warranted specific description. However, the present specimen shows changes in both pigmentation and spination that should be mentioned.

Overall pigmentation has become much denser, with the body showing six heavy bars. These have become more difficult to ascertain, but can be seen by the unaided eye. The last bar caudally is on the peduncle and extends onto the caudal fin, with the pigment lines being evident on all rays. The anal fin contains a larger pigmented area, as does the dorsal fin. The only hyaline area on the dorsal fin is present anterior to the fourth ray. The pectoral fin contains no pigment. The head has become more densely pigmented, with the cranial, opercular, and snout regions remaining the darkest. Subcutaneous pigmentation over the whole head has intensified.

The spination of the head has increased. The snout contains the same number of rows as the previous specimen, but the spines are now present in groups of three predominately. The mandibular rows of spines are the same, but they extend farther anteriorly than before. The spines at the angle of the jaw number six and are connected to the preopercular row of spines. The preopercular row of four spines is unchanged, as are the two stout preopercular spines. The preorbital ridge contains eight spines and the supraorbital ridge contains eleven spines. The cranial group of spines numbers four. The entire head is now covered with singular spines, but they have enlarged considerably from the previous specimen. For the first time there is a clear skin flap extension of the opercle. This flap is spineless. The maxillary contains a few short singular spines. The eye is becoming smaller, being contained 25.3 in the standard length.

The spination of the body has increased extensively over that of the 33.0 mm specimen. The first dorsal row extends from the cranial region to the caudal peduncle and contains four groups of four spines in the central portion. The first ventral row extends from the isthmus

to the caudal peduncle and contains nine groups of four spines centrally. The second dorsal row originates under the 11th dorsal ray and extends well onto the caudal peduncle. This row is composed largely of groups of three spines. The second ventral row is similar, but does not extend onto the caudal peduncle as far as the second dorsal row. The whole lateral aspect of the body is densely spined, with most of the spines being in groups of two. In the region of the anus the second ventral row becomes confused, with a third ventral row extending anteriorly. These rows form a "Y"-shaped structure, as in the previous specimen. In the region of the anus and extending backward there are three small rows of spines, composed of groups of two spines, situated between the second dorsal and ventral rows. These rows continue only a short way over the anal base and then become indistinct. Anterior to the "Y"-shaped pattern of the ventral rows in the region of the anus there are about eleven small rows of spines. The row pattern is slightly confused giving a general scattered appearance of spines in this area.

Specimen No. Reg. 17—68.8 mm. At a glance there appears to be little change in this specimen, except for pigmentation and spination. The body has elongated somewhat, but this can be expected from the straight line relationships that are obtained from the body measurements. The eye remains essentially the same in proportion, being contained 22.9 in the standard length. The height of the fins has increased, but as yet there is no interruption of either anal or dorsal base as occurs in the adult. The caudal fin has become slightly forked and has reached its completed development at the ray's bases. The pectoral rays have lengthened considerably, and the fin for the first time is slightly falcate (Figure 9).

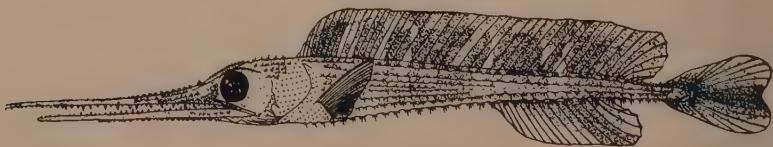


FIGURE 9. 68.8 mm, specimen No. Reg. 17.

The pigmentation is fairly uniform over the entire specimen, with only the ventral half showing any change in density. The barring pattern is still evident only now there are seven bars instead of five, these being slightly darker than before. The pigmentation on the dorsal fin

has increased considerably, and is opaque in most areas. Several small hyaline spaces remain and these are distributed over the interradiial membrane. All dorsal elements for the first time can be identified as rays. This leads to the supposition that *X. gladius* has no spinous rays at any stage of development. The pectoral rays exhibit small rows of spines (resembling serrations) about halfway to the tip from the base. This occurs on the first eight rays counting from the origin toward the insertion.

The spination of the head has increased to the extent that there is not a clear spot left, with the exception of the extreme tip of the mandible and premaxillary. The rows of spines on the snout are enlarged and interspaced with many additional groups of spines (mostly in twos). In the dorsal median row there is one group of four spines. The preorbital ridge now contains fourteen spines and has extended in area. The supraorbital ridge has also extended and contains seventeen spines. The opercular apparatus also contains numerous small groups of two spines as do the maxillary and the isthmus. The mandibular row of spines now extends about three fourths the way to the tip.

The spination of the body has increased, the body being entirely covered with spines. Most of these spines are in groups of two, except for the four predominate rows. The dorsal row contains groups of three at the distal ends and groups of four in the central two thirds. The ventral row is composed almost entirely of groups of four. Both of these rows continue back to the edge of the caudal base and merge on the midline of the body. Above and below these two arches on the caudal base are several additional rows of small groups of two spines that cover the posterior portion of the peduncle. The second dorsal row is made up of groups of three spines and begins under the 8th dorsal ray, just under the first dorsal row. Both this row and the second ventral row are made up of groups of three spines and they continue posteriorly ending at the junction of the first dorsal and ventral rows. The bases of these four rows have ossified and give the appearance of lumps in the skin. Anterior to the anus there is no confusion in the second ventral row and the "Y"-shaped appearance of this row, as in the previous specimen, is absent. The additional four rows of small spines are still present between the second dorsal and ventral rows, giving a total of eight rows in this area of the body.

The teeth in the upper jaw have decreased in size but have increased tremendously in number. There are now 137 ± 5 on one side of the

jaw. There is for the first time a series of small outward pointing teeth above the main series. The mandibular teeth number 214 ± 5 on one side of the jaw. The mandible possesses a series of small outward pointing teeth below the main series and an additional series of small teeth inside the main series.

Specimen No. S.C.—192.1 mm. In general the body pigmentation of this specimen is dense, with only the ventral one-fifth of the lateral aspect lacking pigment. The barred pattern is still present, but the bars are irregularly spaced and differ in width. Seven bars are present, the posterior-most including the caudal peduncle and the caudal fin. The head remains in a densely pigmented state, with a prominent band running obliquely upward and back from the front of the maxillary through the eye to the posterior edge of the opercle. This band seems to continue onto the body behind the pectoral rays and merges with the anterior-most bar. Both the dorsal and anal fins were damaged and the interradi al membrane largely digested away. The drawing (Figure 10) represents a reconstruction of both of these fins and the color pattern has been surmised from the previous specimen and from remains of the fins. The snout and mandible were broken about midway and the skin digested away from the anterior most one third of both jaws. The teeth likewise had been damaged and only broken remnants can be seen ahead of the break in the jaws. Other than this and the fact that the caudal fin is slightly bent the specimen is in excellent condition. For the first time the pectoral fin is pigmented. This pigmentation is represented in the medial rays of the fin and continues from the base to the tip.

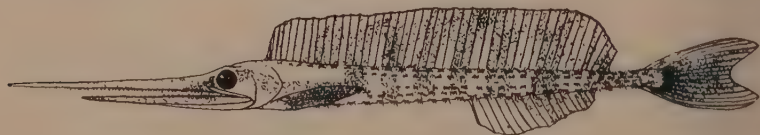


FIGURE 10. 192.1 mm, specimen No. S. C.

The spination of the specimen is highly developed, with both the body and the head densely covered with minute spines (mostly in small groups of three spines). This heavy spination gives the whole specimen a granular appearance. The four rows of keeled spines have enlarged and hold positions similar to that found in previous specimens. The dorsal and ventral rows now contain spines in groups of five in the central two thirds and groups of four distally. The second

dorsal and second ventral rows consist mainly of groups of four spines, with a few groups of five spines centrally. The second ventral row seems to originate over the anus where two other rows meet it and continue forward (=—). The second dorsal row originates under the 16th dorsal ray and turns medially at the caudal base. The first ventral row originates under the pectoral base and turns medially at the caudal base. The first dorsal row originates under the fifth dorsal ray and terminates with the first ventral row. In between these major rows of spines there are many groups of three spines that adhere to special pattern, and which cover the body completely.

The spination of the head has changed considerably. The snout no longer has rows of spines, and both the preorbital and supraorbital ridges have disappeared leaving only a slight serration over the eye. The temporal spines and the small group of spines on the dorsal surface of the opercle have disappeared. The spines on the preopercle have degenerated into a mildly serrate condition, and the two large preopercular spines are gone. The angle of the lower jaw has lost its large row of spines. In general the whole spination of the head has decreased. However, these heretofore large spines have been replaced by a general over all spination that looks mildly granular, but lacks any specific pattern.

The teeth at this stage have decreased in size, but have considerably increased in number. There now is one continuous row of teeth on the outer margin of both jaws, with several additional bands of villiform teeth on the inner margins. These villiform teeth continue to the tips of both jaws.

The proportions of the fish have changed slightly resulting from a general elongation of the body. The eye is now contained 31.5 in the standard length. For the first time there is a slight shortening of the mandible as it is contained 1.2 in the snout (refer to tables).

The dorsal and anal fins have decreased slightly in height although the bases remain essentially as they have in the previous specimens. The caudal fin has increased in length and the rays have fully developed. The caudal is more deeply forked, although it has not reached its final form. The pectoral has increased in length, all rays have formed, and is more falcate than the pectoral of the previous specimen. Small spines appearing as serrations are present on all pectoral rays, all caudal rays and on the first stout rays of the anal and dorsal fins. A few other rays of the dorsal and anal fins have these serrations, but they do not cover the entire length of the ray.

SCALE DEVELOPMENT

From a standard length of 9.0 mm in this series, spinous scales are in evidence. As the specimens increase in size these scales develop, going from single spines at their onset to large keeled structures containing five recurved conical spines (Figure 11). At the smallest stage the spine is an osseous protrusion from the skin surface pointing upward. These protrusions contain a dense center, with a point at the apex. These structures are spinous scales in their single phase.

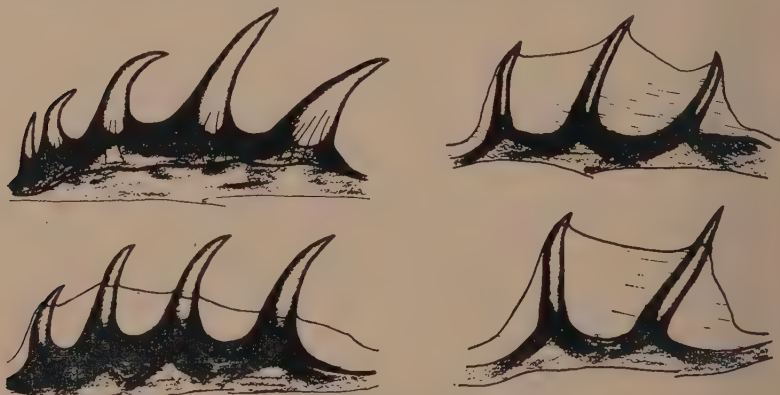


FIGURE 11. Various stages of scale development taken from the first ventral row of spines.

At 12.1 mm the scales possess two definite conical spines. The bases of these scales are slightly raised from the dermal surface forming a hump. An osseous partition is present and connects the spines almost all the way to the tip. These bases of the conical spines are enclosed in skin tissues and do not form a true common base.

At 14.5 mm the scale has three conical spines, with the osseous partition still connecting the individual spines almost to the tip. Here the spines are slender with their bases connected, forming a shallow common base. As the presence of this common base becomes evident the total dorsal aspect of the base becomes elliptically shaped.

Developing further, the scales enlarged in area and possess four large recurved spines. This occurs for the first time at 55.4 mm. Still conical in shape, these spines have a heavy base which spreads over more area. At this stage the osseous partition is smaller and connects the spines for about half their length. When the ventral or dorsal rows

of spines on the body are seen in this condition it gives the appearance of a series of humps running together, with the osseous partitions and the spine tips resembling a continuous keeled row.

The greatest development in this series is the presence of five recurved spines per scale which occurs in the 192.1 mm specimen. At this stage the osseous partition is absent and the base of the spines have increased in depth. There is a widening of the base and an increase in circumference of the spines. In this condition the rows of spines are more evident on the body. The bases of the scales in the rows are almost connected giving a strong keeled effect.

In all cases, except the groups of three spines, the posterior most spine of the scale is the strongest and usually the longest. However, there is considerable variation among the scales and almost any combination can be present. Often distance between spines varies as does the spine height of different scales. The rows of scales may contain two or three different stages of scale development, indicating that all scales are not formed at one time. On almost all specimens the largest scales and the scales containing the greatest number of spines appear in the central one third of either the first ventral or first dorsal row. Nowhere in this series were groups of seven spines seen, but several scales containing six spines were observed on the largest specimen (192.1 mm). The scales of the largest specimen are strong and cover the entire body, which leads us to a consideration of the size at which the scales are lost. Nakamura *et al* (1951), discuss the scales at various sizes larger than 192.1 mm. At 252 mm they found scales still existing, but about half were smooth. They concluded that the scales are deciduous in some stage of growth. They discuss a 454 mm specimen pointing out that the scales have degenerated conspicuously, being embedded in the skin, with their existence still traceable exteriorly. They mention a specimen 580 mm with the scales totally absent. LaMonte & Marcy (1941) report the skin of a four foot specimen, "thickly set with irregularly set overlapping, somewhat triangular-shaped scales, each bearing a series of from three to ten small, transparent, sharp, recurved spines." Also Lutken (1880) refers to scales on a specimen 27 inches long. From these conflicting views it must be concluded that during postlarval life the swordfish has scales present from about 9.0 mm to some stage beyond four feet.

GENERAL DEVELOPMENT

In Figures 12 to 17 various body parts are compared as percentages

of standard length. Each dot and circled dot represents one specimen measured by the author, the dots being those from the South Atlantic Coast of U. S. and the circled dots those from the Gulf of Mexico. The additional geometric figures on the graphs represent specimens that were not measured by the author. Percentages from the specimens labeled Sanzo, 1922 and Sanzo, 1930 were taken from the original drawings; percentages from the specimens labeled LaMonte & Marcy, 1941 were taken from drawings and photographs presented in that paper; percentages from the specimen labeled Lutken, 1880 and Cuvier and Valenciennes, 1831 were taken from facsimile reproductions of the original drawings presented by Goode (1883); and percentages from specimens labeled Gregory and Conrad, 1937 were obtained from measurements presented in that paper. Previous mention has been made concerning the specimen from Nova Scotia and the ten specimens from Cuba.

In discussing the percentage graphs, mention will be made to different stages of larval growth. Considering the figures used by Sanzo (1922) and Sella (1911) it seems necessary to split the term larval into several groups. From the point in development when the yolk sac has been absorbed, up to the point when body scales are evident is designated as early larval. This includes Sanzo's specimen of 5.56 mm up to specimen No. 18 at 9.0 mm. At this latter size the head spination has increased and body scales are in evidence. The term middle larval is applied until spination of the head has started to decrease (this includes specimen No. 18 at 9.0 mm through specimen No. Reg. 72 at 72.5 mm). The term late larval is applied to the 192.1 mm specimen which has lost the characteristic head spines. The term juvenile is used to represent the small adult and is attained when all body spines are completely lost. The definition of terms dealing with larval stages as set forth by C. L. Hubbs, Copeia 1943, No. 4, have not been used since the division of these stages in this study is based on head and body spines.

The early larval specimens available are specimen Nos. A1, Reg. 73, and A2. In specimen No. A1 a divergent character is present which is not figured in Sanzo's drawing at 6.40 mm. The supraorbital ridge of spines does not continue around the orbit and connect with the preopercular ridge as Sanzo has figured, but continues back forming a subcutaneous connection with the cranial spine. This is not evident in the 7.8 mm specimen where the supraorbital ridge is seemingly directed toward the temporal spine (Figure 2). There seems to be no

reason for this continuation of the ridge in the 6.1 mm specimen except for the large amount of variation of characters in these smaller specimens.

In the middle larval stage spination on the head and body undergoes a progressive change represented by an increasing spination of these parts. In the interval from 72.5 mm to 192.1 mm, the head spination has undergone considerable change and, except for the granular spination, all major spines have been lost.

No juvenile specimens were obtained although the 1194 mm specimen from Cuba and the 1295 mm specimen from Lamonte and Marcy (1941) are both fairly close (these could be better termed late juveniles). Specimens C2 and C3 are designed as early adults and from 2057 mm to 3607 mm are considered full adults.

While keeping these groups in mind it must be remembered that the use of four cycle semi-log graph paper tends to compress the curves in the last cycle giving the appearance that the period from late juvenile to early adult and adult is attained rapidly.

Figure 12 represents the curve for percent of snout against standard

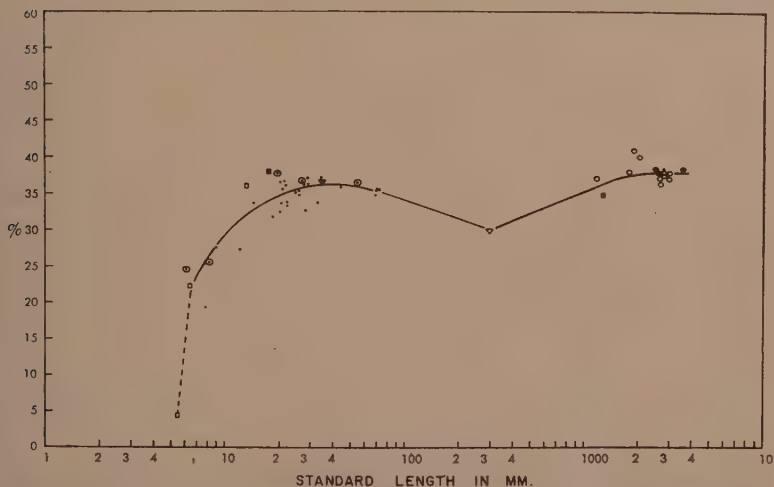


FIGURE 12. % of snout length against standard length. Dots represent *T. N. Gill* specimens, circled dots represent *Alaska* specimens, open squares represent Sanzo's specimens, solid squares represent LaMonte & Marcy's specimens, the open triangle represents Cuvier & Valenciennes' specimen, the solid triangle represents Lutken's specimen, open circles represent Cuban specimens, and large solid dots represent Gregory & Conrad's specimens.

length. From this curve development of the snout can be seen in all the above-mentioned stages. The dashed line represents percentages from Sanzo's figures and indicates a rapid development at this early stage. The extent of development from the middle larval period to the adult can be seen from the steeply rising curve which peaks around 40 mm (36.5%), gradually decreases to the late larval stage (32%), rises through the late juvenile and stabilizes at about 38% in the adults. The dip in the curve at 192.1 mm was at first thought to be due to a variant, but the percentage obtained from Cuvier and Valenciennes (1831) helps to verify the apparent metamorphosis which takes place from late larval to juvenile stages.

The curve for percent of mandible against standard length (Figure 13) does not indicate any abrupt changes during the late larval and juvenile stages. Rapid early larval development is present, but the peak of the middle larval development comes earlier at around 14 mm; about 37%. From this point there is a fairly uniform decrease in percentage through all stages until it stabilizes in the adult at about 10%.

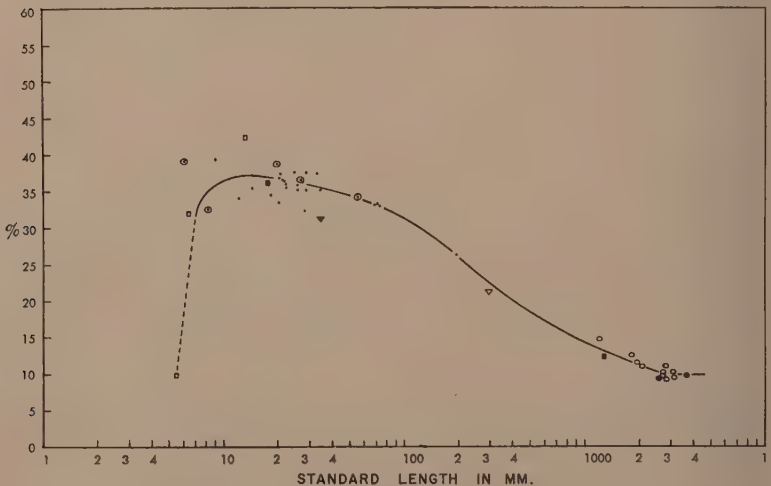


FIGURE 13. % of mandible length against standard length. Dots represent *T. N. Gill* specimens, circled dots represent *Alaska* specimens, open squares represent Sanzo's specimens, solid squares represent LaMonte & Marcy's specimens, the open triangle represents Cuvier & Valenciennes' specimen, the solid triangle represents Lutken's specimen, open circles represent Cuban specimens, and large solid dots represent Gregory & Conrad's specimens.

The percentage graph for the head against standard length (Figure 14) indicates a situation similar to the snout curve; this is to be expected as the snout is the major portion of the head with the postorbital remaining relatively stable throughout the whole series. (Refer to Table 4.) The major variation in the head curve and the curve for the snout is present in middle larval development. The early larval period is characterized by a rapid increase peaking at about 15 mm and 50%. From this point there is a uniform decrease through the late larval period to about 41%. Then a gradual increase through the juvenile period is found, stabilizing at 50.0% in the adult.

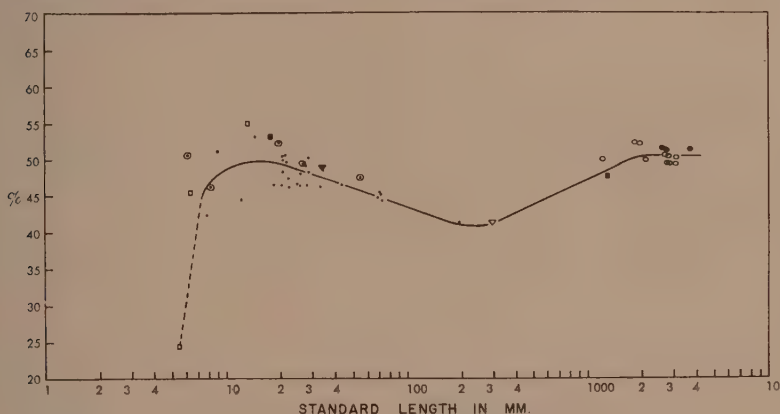


FIGURE 14. % of head length against standard length. Dots represent *T. N. Gill* specimens, circled dots represent *Alaska* specimens, open squares represent Sanzo's specimens, solid squares represent LaMonte & Marcy's specimens, the open triangle represents Cuvier & Valenciennes' specimen, the solid triangle represents Lutken's specimen, open circles represent Cuban specimens, and large solid dots represent Gregory & Conrad's specimens.

Figure 15 represents the body percent against the standard length and is necessarily the inverse curve of the head percent. The body percent falls rapidly from 75.3% at 5.56 mm to a low of 49.5% at about 15 mm. The percent then rises to a peak in the late larval stage of about 58.5% at about 250 mm and then recedes to the adult percent at about 49%.

The curve for eye diameter percent against standard length (Figure 16) shows the typical rise in percentage during the early larval period, but peaking at about 11.5% in the middle of this stage. From 6.1 mm there is a steady downward trend through all the larval stages with the

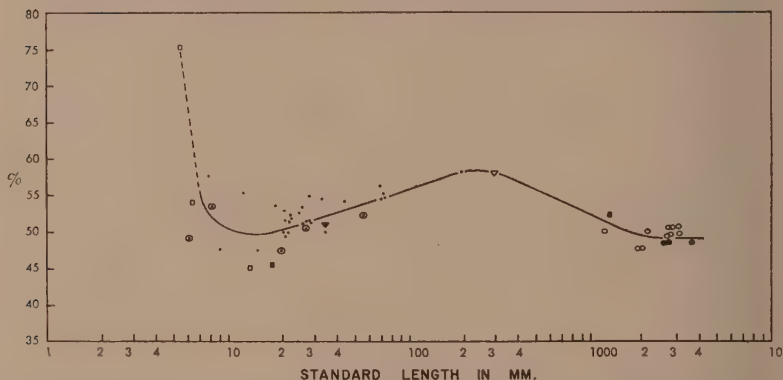


FIGURE 15. % of body length against standard length. Dots represent *T. N. Gill* specimens, circled dots represent *Alaska* specimens, open squares represent Sanzo's specimens, solid squares represent LaMonte & Marcy's specimens, the open triangle represents Cuvier & Valenciennes' specimen, the solid triangle represents Lutken's specimen, open circles represent Cuban specimens, and large solid dots represent Gregory & Conrad's specimens.

percent stabilizing at about 3% in the late larval stage (192.1 mm). This character indicates the least amount of variation of all characters studied.

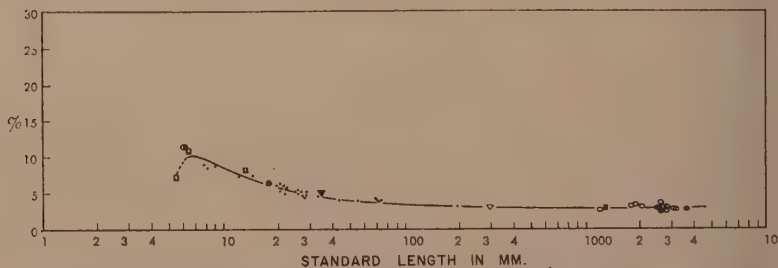


FIGURE 16. % of eye diameter against standard length. Dots represent *T. N. Gill* specimens, circled dots represent *Alaska* specimens, open squares represent Sanzo's specimens, solid squares represent LaMonte & Marcy's specimens, the open triangle represents Cuvier & Valenciennes' specimen, the solid triangle represents Lutken's specimen, open circles represent Cuban specimens, and large solid dots represent Gregory & Conrad's specimens.

The head depth percent against the standard length (Figure 17) was only available from the specimens the author measured (6.1 mm to 192.1 mm). In the case of percentages that were taken from draw-

ings two were considered valid, those of Lutkin (1880) and Cuvier and Valenciennes (1831). These were not indicated on the graph as they fell exactly in line. No other measurements from drawings were usable because of the distorted condition of the jaws. Although the origin of this curve fits the data presented it is the author's opinion, based on figures from Sanzo (1922) and Sella (1911), that if standard head depths were available from the smaller sizes (5 mm) the curve would present a sharp rise in the early larval period from about 10% at the onset to about 19% at 9.5 mm (as indicated on the graph). From 9.5 mm the percentages decrease through the larval stages reaching a low of 6% at 192.1 mm in the late larval stage.

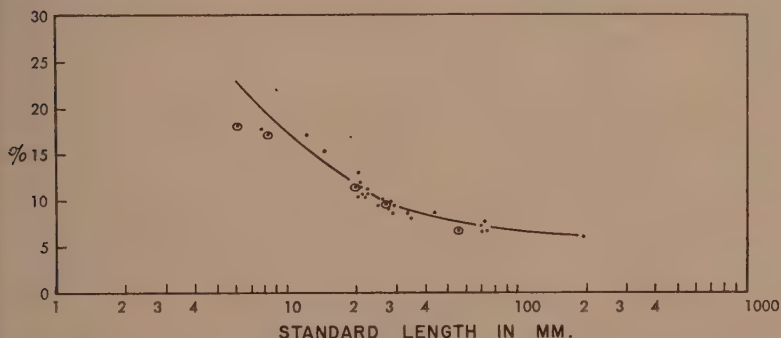


FIGURE 17. % of head depth against standard length. Dots represent *T. N. Gill* specimens, circled dots represent *Alaska* specimens, open squares represent Sanzo's specimens, solid squares represent LaMonte & Marcy's specimens, the open triangle represents Cuvier & Valenciennes' specimen, the solid triangle represents Lutken's specimen, open circles represent Cuban specimens, and large solid dots represent Gregory & Conrad's specimens.

A curve for greatest depth was not included because the contents of the gut greatly confused the percentages and caused undue variation. By inspection of the percentage figures (Table 3) it can be seen that such a curve would resemble head depth through all the larval development.

In Figure 18 are represented lengths of various body parts plotted against standard length for specimens from 6.1 mm to 192.1 mm. These curves, augmented by the data contained in Tables 3 and 3, illustrate the way in which these body parts are developing. It can be seen from the curve that the mandible is the longest structure in the head until about 30 mm, at which time the snout exceeds the man-

dible. The body and the head begin at almost equal lengths following which there is a gradual elongation of the body throughout the larval development.

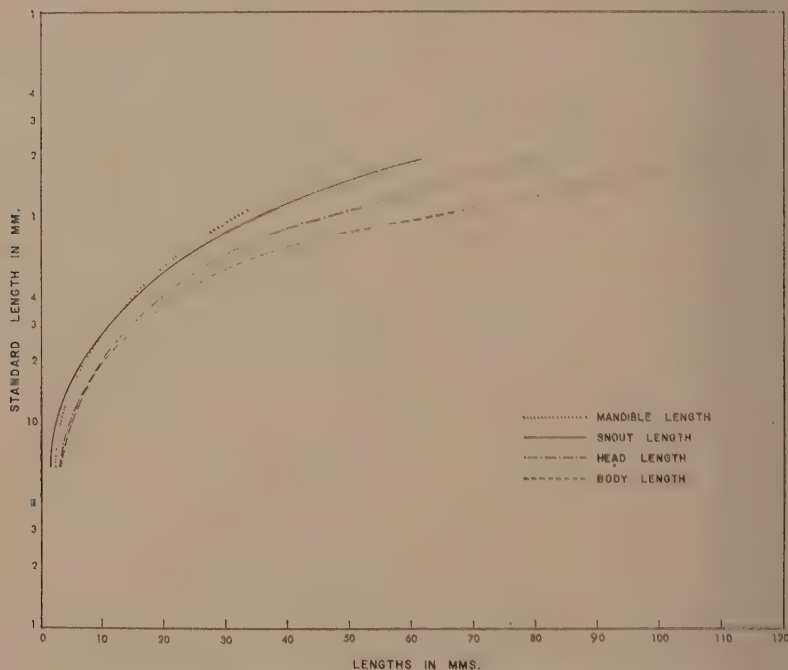


FIGURE 18. Various body part lengths against standard length.

Figure 19 shows in histogram form the ray counts of various fins. The dorsal fin shows considerable variation, which is probably due to a differential development of the fin rays. In all fins, ray development seems to be in a posterior-anterior direction which leaves the rays at the origin of the fins difficult to discern until the fins have completed development. All fins in which there was any doubt as to the validity of the count were omitted from the graph. All fin counts are contained in Table 2.

BODY PROPORTIONS

For a quick look at how the various body measurements are changing, a proportion table (Table 4) has been constructed. Only the

TABLE 3. BODY PART PERCENTAGES OF STANDARD LENGTH

Specimen No.	Sanzo, 1922	A1	Sanzo, 1930	Reg. 73	A2	18	19	Sanzo, 1922	17	LaMonte & Marcy, '41	15
Standard length in mm	5.56	6.1	6.40	7.8	8.2	9.0	12.1	13.24	14.5	17.6	18.2
Body	75.3	49.2	54.2	57.7	53.6	47.8	55.4	45.2	47.6	45.7	53.8
Head	24.4	50.8	45.6	42.3	46.3	51.1	44.6	55.0	53.1	54.2	46.7
Snout	4.6	24.6	22.4	19.2	25.6	27.8	27.3	36.1	33.8	38.1	31.9
Mandible	10.0	39.3	32.1	28.2	32.9	39.5	34.2	42.7	35.6	36.4	34.7
Maxillary	—	19.7	—	16.7	15.8	15.1	12.6	—	11.4	—	10.2
Postorbital	12.4	14.6	12.6	14.1	12.2	13.3	9.9	10.6	11.7	9.4	8.8
Caudal fin	—	3.3	—	3.8	3.7	3.3	3.3	—	9.7	—	7.1
Snout to dorsal origin	—	47.5	—	43.6	46.3	59.3	50.5	—	52.3	—	48.3
Snout to anal origin	—	70.5	—	73.1	76.8	83.7	78.4	—	73.1	—	75.6
Snout to pectoral origin	—	52.4	—	41.0	46.3	57.0	48.6	—	49.0	—	50.6
Greatest depth	—	13.1	—	15.4	18.3	22.1	17.1	—	15.4	—	16.5
Head depth	—	18.0	—	17.9	17.1	22.1	17.1	—	15.4	—	16.5
Depth at anus	—	8.2	—	11.5	9.8	14.0	8.1	—	7.4	—	5.1
Depth at peduncle (ant. margin)	—	4.9	—	5.1	4.9	4.7	4.5	—	4.0	—	4.0
Depth at snout (post. margin)	—	9.8	—	9.0	9.8	9.3	8.1	—	8.1	—	8.0
Eye diameter	7.2	11.5	11.0	9.0	8.5	8.9	7.4	8.3	7.6	6.7	6.6
Dorsal base	—	36.1	—	43.6	40.2	34.9	47.7	—	45.6*	—	47.7
Anal base	—	14.6	—	15.4	11.0	10.5	15.3	—	30.9	—	17.6
Pectoral base	—	4.9	—	6.4	4.9	7.0	7.2	—	5.4	—	4.5

*Not accurate because of uncertain measurement.

TABLE 3. (Continued)

Specimen No.	A3	8	9	11	16	6	12	13	5	7	10
Standard length in mm	19.8	20.2	20.4	20.7	20.8	21.2	21.9	22.1	22.1	24.8	25.8
Body	47.5	53.0	50.0	51.7	49.5	50.0	51.6	52.0	52.5	52.8	53.5
Head	52.5	46.5	50.5	43.8	50.0	50.9	49.8	47.5	46.2	46.8	46.5
Snout	37.9	32.7	36.8	33.8	35.6	36.8	36.1	33.9	33.5	35.1	35.3
Mandible	38.9	33.7	37.0	37.5	30.7*	36.8	36.5	36.0	35.7	32.7	36.0
Maxillary	11.1	8.5	8.5	7.0	9.0	9.9	9.1	8.9	10.0	8.5	9.3
Postorbital	8.1	7.9	7.8	7.7	8.7	9.0	6.8	8.1	8.1	6.5	8.1
Caudal fin	9.6	9.4	10.3	10.1	8.2	9.0	8.7	8.6	8.6	6.0	8.1
Snout to dorsal origin	54.0	47.7	50.0	49.0	50.8	49.5	48.9	49.5	46.6	46.4	47.7
Snout to anal origin	73.7	74.9	74.5	74.0	75.9	75.9	75.3	72.9	72.4	68.5	77.1
Snout to pectoral origin	53.0	49.7	51.0	49.0	51.3	51.4	49.3	49.1	46.6	46.4	48.4
Greatest depth	9.1	13.1	12.0	12.0	11.6	11.8	12.8	11.2	11.8	11.7	10.1
Head depth	11.6	13.1	11.5	12.0	11.6	10.8	10.5	11.2	10.9	9.7	10.1
Depth at anus	5.1	5.5	4.5	4.5	5.0	4.2	6.4	4.7	5.0	4.4	5.0
Depth at peduncle	3.0	3.0	3.0	3.0	3.0	2.8	3.2	2.8	2.7	3.2	3.1
(ant. margin)											
Depth of snout	5.1	5.5	7.0	6.5	6.0	6.1	6.4	5.1	6.8	6.5	5.8
(post. margin)											
Eye diameter	6.1	5.9	5.3	6.3	5.8	6.1	5.0	5.9	5.9	5.2	5.4
Dorsal base	46.5	48.7	49.5	45.5	42.7	47.2	47.9	48.1	49.3	45.6	46.5
Anal base	16.7	18.6	17.0	17.0	16.1	17.5	16.9	16.8	19.0	15.7	17.1
Pectoral base	4.0	4.5	4.0	4.0	4.0	3.8	3.2	3.3	4.1	3.6	3.5

*Not accurate because of uncertain measurement.

TABLE 3. (Continued)

Specimen No.	14	A4	4	3	Reg. 61	2	Reg. 39	1	Lutken, 1880	T.O. 1	A5
Std. length in mm	25.8	26.9	27.2	28.0	28.6	28.7	33.0	34.4	34.5	43.7	55.4
Body	51.2	50.6	51.5	55.0	51.4	51.2	54.5	50.0	51.1	54.2	52.5
Head	48.1	49.4	49.3	46.4	50.3	48.4	46.4	48.8	48.8	46.7	47.7
Snout	34.9	36.8	36.4	32.9	37.1	36.2	33.9	37.2	36.8	35.9	36.6
Mandible	35.3	36.8	36.4	32.5	37.8	35.2	37.6	35.2	31.6	34.8*	34.3
Maxillary	9.3	8.5	8.8	8.6	9.8	8.0	8.5	9.0	—	7.3	6.9
Postorbital	8.1	7.4	7.7	7.5	8.0	8.0	7.0	6.7	7.3	6.6	6.9
Caudal fin	8.9	8.9	9.9	7.5	9.1	8.7	9.4	9.9	—	8.9	9.0
Snout to dorsal origin	47.3	48.7	47.8	45.7	51.0	48.8	42.7	49.4	—	46.0	46.0
Snout to anal origin	80.2*	76.2	72.8	75.0	73.8	76.3	73.6	74.1	—	72.5	73.5
Snout to pectoral origin	48.8	48.7	48.5	46.4	49.0	49.1	42.4	49.1	—	45.3	47.1
Greatest depth	10.1	8.2	10.3	10.0	9.1	9.8	10.3	8.1	—	8.2	6.0
Head depth	10.1	9.7	9.2	10.0	8.7	9.8	8.8	8.1	—	8.7	6.9
Depth at anus	4.7	4.1	4.8	4.6	4.5	4.9	4.2	4.1	—	2.7	3.4
Depth at peduncle (ant. margin)	3.1	2.2	3.3	3.2	3.1	3.5	3.0	2.9	—	2.5	2.0
Depth of snout (post. margin)	5.4	4.8	5.1	5.0	5.2	4.9	5.5	4.9	—	4.1	3.4
Eye diameter	5.0	5.2	4.8	4.6	4.9	5.2	4.8	4.9	5.0	4.1	4.0
Dorsal base	45.7*	51.7	47.4	50.0	49.3	47.0	50.3	47.4	—	50.6	46.7
Anal base	17.8	17.1	20.2	18.2	16.8	17.8	19.7	18.0	—	17.9	17.7
Pectoral base	2.7	2.2	2.9	3.2	3.1	2.8	3.3	2.9	—	3.0	2.5

*Not accurate because of uncertain measurement.

TABLE 3. (Continued)

Specimen No.	Reg. 17	Reg. 53	N.G. 38	Reg. 72	S.C.	Cuv. & Val.		LaMonte & Marcy, 1941			
						1831		C1	C2	C3	C4
Std. L in mm	68.8	70.0	71.2	72.5	192.1	298.2	1194	1295	1797	1905	2057
Body	56.4	54.7	55.3	54.6	58.1	58.1	50.0	52.5	47.7	47.7	50.0
Head	44.9	45.6	45.4	44.6	41.3	41.5	50.0	47.8	52.3	52.3	50.0
Snout	34.9	35.6	35.7	35.7	32.0	30.0	37.3	35.0	38.2	41.3	40.2
Mandible	33.3	33.3	—	33.1	26.5	21.3	14.9	12.6	12.7	11.7	10.2
Maxillary	7.1	6.0	6.9	6.6	5.2	—	—	—	—	—	—
Postorbital	6.0	6.4	6.3	6.2	6.4	8.6	10.1	10.3	11.0	7.7	6.8
Caudal fin	9.2	9.7	9.7	11.6	12.0	—	13.8	—	11.7	17.3	12.3
Snout to dorsal origin	43.8	44.4	44.4	44.8	40.3	—	—	—	—	—	—
Snout to anal origin	71.2	70.6	73.3	73.4	71.0	—	—	—	—	—	—
Snout to pectoral origin	50.9	44.6	45.6	45.5	41.5	—	—	—	—	—	—
Greatest depth	7.3	7.6	7.4	6.9	6.7	—	—	—	—	—	—
Head depth	7.3	6.9	7.9	6.9	6.2	—	—	—	—	—	—
Depth at anus	3.8	4.0	4.1	4.0	4.7	—	—	—	—	—	—
Depth at peduncle (ant. margin)	2.6	2.4	2.5	2.3	2.8	—	—	—	—	—	—
Depth of snout (post. margin)	3.6	3.7	3.4	3.7	3.4	—	—	—	—	—	—
Eye diameter	4.4	4.1	3.9	4.0	3.2	3.2	2.7	3.0	3.2	3.4	3.1
Dorsal base	47.8	49.0	48.9	48.8	50.6	—	—	—	—	—	—
Anal base	17.7	20.1	16.8	19.0	17.2	—	—	—	—	—	—
Pectoral base	2.5	2.9	2.8	2.5	2.6	—	—	—	—	—	—

more important measurements are used plus some proportions that are not indicated in the percentage table.

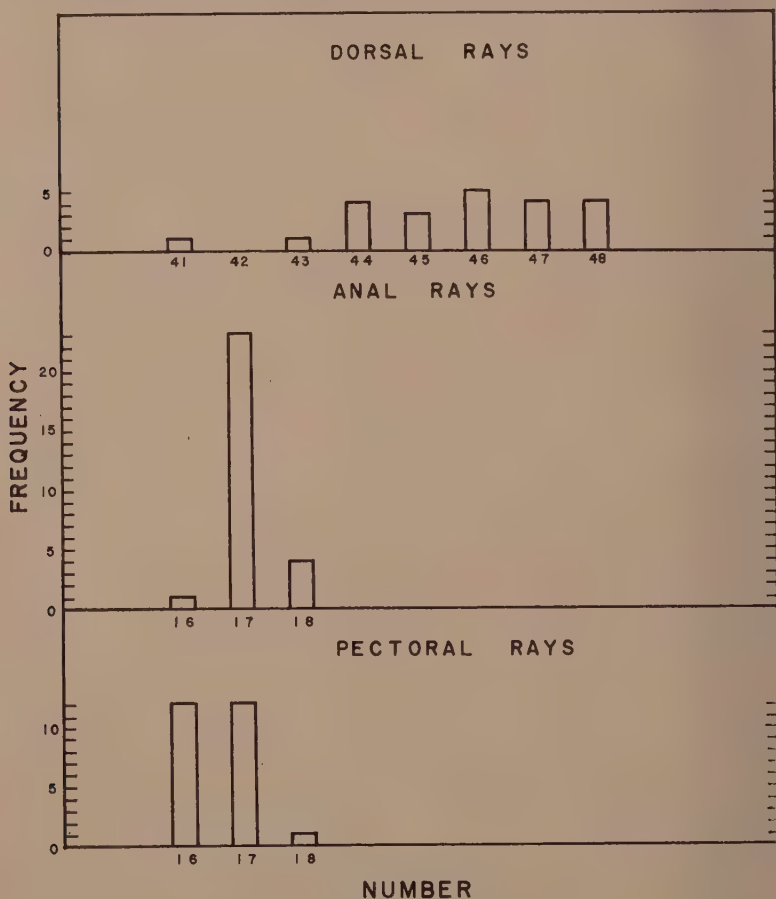


FIGURE 19. Frequency of fin ray counts.

In comparing the ratios it must be remembered that there is a large amount of variation in all the specimens. In the transitional stages (192.1 mm and 1194 mm) the proportions are characteristic of one specimen, which is not too desirable considering the variation that is present.

TABLE 4. BODY PROPORTIONS

Specimen No.	A1	Reg. 73	A2	18	19	17	15	A3	8	9	11	16
Std. L in mm	6.1	7.8	8.2	9.0	12.1	14.5	18.2	19.8	20.2	20.4	20.7	20.8
SL/ML	0.63	0.68	0.78	0.74	0.87	0.92	0.95	0.97	0.99	1.01	0.93	1.21*
HL/SL	2.07	2.20	1.81	1.84	1.64	1.57	1.47	1.39	1.42	1.37	1.43	1.41
HL/ML	1.29	1.50	1.41	1.35	1.42	1.45	1.39	1.35	1.40	1.39	1.33	1.70*
HL/ED	4.43	4.71	5.43	5.75	6.00	7.00	7.08	8.67	7.83	8.58	7.69	8.67
HL/Po	3.44	3.00	3.80	3.83	4.50	4.53	5.31	6.50	5.88	6.44	6.25	5.78
Std. L/HL	1.97	2.36	2.16	1.96	2.24	1.88	2.14	1.90	2.15	1.98	2.07	2.00
Std. L/BL	2.03	1.73	1.86	2.09	1.81	2.10	1.86	2.11	1.89	2.00	1.93	2.02
Std. L/ED	8.71	11.14	11.71	11.25	13.44	13.18	15.17	16.50	16.83	17.00	15.92	17.33
Std. L/SL	4.07	5.20	3.90	3.60	3.67	2.96	3.14	2.64	3.06	2.72	2.96	2.81
Std. L/ML	2.54	3.55	3.04	2.65	3.18	2.74	2.98	2.57	3.01	2.76	2.76	3.41*
Std. L/CFL	30.50	26.00	27.33	30.00	30.25	10.36	14.00	10.42	10.63	9.71	9.86	12.24
Std. L/HD	5.55	5.57	5.86	4.74	6.37	6.30	6.28	8.61	7.77	8.87	8.63	9.04

*Derived from uncertain measurements.

Note: SL = Snout length, ML = Mandible length, HL = Head length, ED = Eye diameter, Po = Postorbital, Std. L = Standard length, BL = Body length, CFL = Caudal fin length, and HD = Head depth.

TABLE 4. (Continued)

Specimen No.	6	12	13	5	7	10	14	A4	4	3	Reg. 61	2
Std. L in mm	21.2	21.9	22.1	22.1	24.8	25.8	25.8	26.9	27.2	28.0	28.6	28.7
SL/ML	1.00	0.99	0.97	0.94	1.07	0.98	0.99	1.00	1.00	1.01	0.98	1.03
HL/SL	1.37	1.38	1.40	1.38	1.33	1.32	1.38	1.34	1.35	1.41	1.36	1.34
HL/ML	1.37	1.36	1.36	1.29	1.43	1.29	1.36	1.34	1.35	1.43	1.33	1.38
HL/ED	8.23	9.91	8.08	7.85	8.92	8.57	9.54	9.50	10.31	10.00	10.29	9.27
HL/Po	5.63	7.27	5.83	5.67	7.25	5.71	5.90	6.65	6.38	6.19	6.26	6.04
Std. L/HL	1.98	1.92	2.10	2.17	2.14	2.15	2.08	2.02	2.03	2.15	1.99	2.06
Std. L/BL	2.00	1.94	1.92	1.91	1.89	1.87	1.95	1.98	1.94	1.82	1.95	1.95
Std. L/ED	16.31	19.91	17.00	17.00	19.08	18.43	19.85	19.21	20.92	21.54	20.43	19.13
Std. L/SL	2.72	2.77	2.95	2.99	2.85	2.84	2.87	2.72	2.75	2.04	2.70	2.76
Std. L/ML	2.72	2.74	2.87	2.80	3.06	2.77	2.84	2.72	2.75	3.08	2.65	2.84
Std. L/CFL	11.16	11.53	11.63	11.63	16.53	12.29	11.22	11.21	10.07	13.33	11.00	11.48
Std. L/HD	9.22	9.52	9.21	9.21	10.33	9.92	9.92	10.35	10.88	10.00	11.44	10.25

TABLE 4. (Continued)

Specimen No.	Reg. 39	l	T.O. l	A5	Reg. 17	Reg. 53	N.G. 38	Reg. 72	S.C.	C1	C2	C3
Std. L in mm	33.0	34.4	43.7	55.4	68.8	70.0	71.2	72.5	192.1	1194	1797	1905
SL/ML	0.90	1.06	1.03*	1.07	1.05	1.07	—	1.08	1.20	2.50	3.00	3.55
HL/SL	1.37	1.31	1.30	1.30	1.29	1.28	1.27	1.27	1.30	1.34	1.37	1.27
HL/ML	1.23	1.39	1.34*	1.39	1.35	1.37	—	1.37	1.57	3.35	4.10	4.49
HL/ED	9.56	9.88	11.33	12.00	10.30	11.00	11.53	11.31	13.10	18.66	16.49	15.58
HL/Po	6.65	7.30	7.03	6.95	7.54	7.09	7.18	7.29	6.55	4.98	4.77	6.83
Std. L/HL	2.16	2.05	2.14	2.10	2.23	2.19	2.20	2.21	2.40	2.00	1.91	1.91
Std. L/BL	1.83	2.00	1.84	1.90	1.77	1.83	1.81	1.83	1.72	2.00	2.10	2.10
Std. L/ED	20.63	20.24	24.28	25.28	22.93	24.14	25.43	25.00	31.49	37.31	31.52	29.76
Std. L/SL	2.95	2.69	2.78	2.73	2.87	2.81	2.80	2.80	3.13	2.68	2.62	2.42
Std. L/ML	2.66	2.84	2.88*	2.92	3.00	3.00	—	3.02	3.77	6.71	7.85	8.58
Std. L/CFL	10.65	10.12	11.21	11.08	10.29	10.29	8.48	8.63	8.32	7.24	8.56	5.77
Std. L/HD	11.38	12.29	11.50	14.58	13.76	14.58	12.71	14.50	16.01	—	—	—

TABLE 4. (Continued)

Specimen No.	C4	G. & C., 1937	C5	G. & C., 1937	C6	N.S.	C7	C8	C9	C10	G. & C., 1937
Std. L in mm	2057	2553	2629	2692	2692	2768	2769	2794	3035	3073	3607
SL/ML	3.93	4.11	3.69	—	3.69	3.82	3.76	4.20	3.63	4.02	4.07
HL/SL	1.26	1.33	1.36	1.34	1.36	1.31	1.33	1.30	1.32	1.32	1.33
HL/ML	4.90	5.48	5.00	—	5.00	5.01	5.01	5.45	4.81	5.30	5.41
HL/ED	16.07	17.38	14.04	18.21	16.07	18.38	16.83	18.21	16.82	17.40	18.18
HL/Po	7.40	5.20	5.23	4.96	5.00	5.50	5.25	5.74	5.38	5.44	5.21
Std. L/HL	2.00	1.93	1.97	1.95	2.02	1.98	1.98	2.02	2.03	1.98	1.95
Std. L/BL	2.00	2.07	2.03	2.06	1.98	2.06	2.02	1.98	1.97	2.02	2.06
Std. L/ED	32.14	33.59	27.67	35.42	32.43	36.42	33.36	36.76	34.10	34.52	35.36
Std. L/SL	2.49	2.58	2.67	2.62	2.74	2.59	2.64	2.62	2.69	2.62	2.58
Std. L/ML	9.80	10.59	9.85	—	10.08	9.92	9.92	11.00	9.76	10.52	10.52
Std. L/CFL	8.10	—	6.67	—	8.83	5.45	9.11	9.57	5.83	10.49	—
Std. L/HD	—	—	—	—	—	—	—	—	—	—	—

* Derived from uncertain measurements.

In order to establish proportional growth of the various body parts and how these proportions are changing, ratios of the head and body to the standard length are discussed. Other parts are compared and contrasted.

It can be seen from the Table that head length to standard length yields a ratio which remains constant from the very smallest specimen through the largest adult. In the early stages there is some variation, but that is expected from what the percentages show. The body length to the standard length shows the same constant ratio which, with only slight variations, remains stable from smallest to largest inclusive. With these two ratios constant, direct proportional growth is indicated, with both the head and the body growing in almost direct proportion from the 6.1 mm stage to the 3607 mm adult. In the case of the ratio of snout to standard length there is some change in the ratio indicating differential growth at various sizes. The postlarval range is 2.56-5.20 and the adult range is 2.42-2.72. In the smallest sizes there is considerable variation, but the ratio maintains a gradual decrease to about 20 mm. At this point the ratio remains essentially constant through the largest adult, indicating almost direct proportional growth after 20 mm. Looking at the snout to head ratio the same picture is presented with a gradual decrease evident from the smallest sizes to about 20 mm, the ratio stabilizing thereafter. Taking the ratio of mandible to standard length the reverse is true. Here the ratio remains essentially stable from the smallest sizes to the transitional stages between 192.1 mm and 1194 mm. At this point there is a sharp increase in the ratio which does not stabilize until about 2100 mm. In the case of the snout, direct proportional growth is established after 20 mm, while in the case of the mandible, direct proportional growth occurs up to the transitional stages, at which point the mandible grows slower than the body. The ratio of mandible to head indicates this same pattern. Now considering the mandible to the snout there is a slight increase from the smallest (6.1 mm) to about 20 mm, which is due to a changing snout. The ratio then stabilizes until the transitional stages are reached, where it increases considerably stabilizing around 2100 mm. This latter change in proportional growth is evidenced by the slowing growth of the mandible, while the snout continues with the same trend that was established as far back as 20 mm.

The ratio of postorbital to head shows a gradual increase from the smallest sizes to the transitional stages, at which point there is a slight drop. It then holds fairly constant through the adult specimens. Caudal

fin length to standard length shows a rather sharp decrease from the smallest sizes to about 20 mm where it then remains fairly stable, but with more variation than is expected. At about 70 mm there is a gradual decrease in the ratio which continues through the transitional stages, but shows considerable variation through the adults. Eye diameter to standard length presents a ratio that shows gradual increase from the smallest sizes through the transitional stages. The ratio then increases sharply and remains fairly stable, but with considerable variation through the adults. Eye diameter to head length indicates this same decreasing proportional growth.

OCCURRENCE AND SPAWNING

It is generally known that the swordfish is worldwide in distribution ranging both north and south of the equator in the Atlantic, Pacific and Indian Oceans, in the Red Sea and in the Mediterranean. Northward distribution extends to northern Norway and the south coast of Newfoundland, and south to 35°.

Commercial fisheries are maintained along the eastern coast of the United States and Canada from Newfoundland south to New York. A small fishery is located in Cuba. Some fish are caught on the western coast of Europe, with the majority being landed in Spain and Portugal. The Mediterranean supports an extensive fishery in the area of Messina, and the Bosphorus and the Sea of Marmora provide a moderate catch. In the Pacific Ocean a fishery exists off the coasts of Chile and Peru, the former providing the place of capture of the current world's record swordfish, 1182 pounds. Other concentrations are present along the west coast of Mexico straggling north to California. Swordfish are caught through the North Equatorial Current, in the area of the Ryukyu Islands, and north in the Kuroshio Current. The Indian Ocean seems relatively barren, but there are reports of occasional fish seen or taken around the Cape of Good Hope. Lutken (1880) reports larvae from near Reunion Island, east of Madagascar.

Throughout the adult distribution, females containing ovaries in various stages of maturity have been captured. To date the area of greatest concentrations of such fish has been in the Mediterranean (Sanzo and Sella). Several years ago LaMonte (1944) reported ripe ovaries from off the north coast of Cuba and more recently, Nakamura *et al* (1951) reported ripe ova from the North Equatorial Current. Reports of fish with "inactive" ovaries have been recorded at various times from New England waters (Fish, 1926; LaMonte and

Marcy, 1941; and Lee, 1942). These incidences give rise to thoughts as to where the major spawning populations are located and at what times of the year spawning takes place.

In the western Pacific, Nakamura, *op. cit.*, reports ripe ova from Minami-torishima in the region of 25° - $17'$ N latitude and 156° - $51'$ E longitude during the month of April. In the Atlantic ripe ova have been reported by LaMonte (1944) from off the north coast of Cuba in August and September (about 23° - $05'$ N latitude and 82° - $25'$ W longitude). In the Mediterranean ripe ova are taken from June to September in the region around the Straits of Messina (about 38° N latitude and 16° E longitude). Hence spawning in these three regions includes the months from April through September.

In line with this, the respective areas of larval capture for each area should be mentioned in the Pacific, larvae have been taken in the North Equatorial and Kuroshio Currents during the month of May, whereas the eggs were taken in April (Nakamura, 1951). This leads Nakamura to the conclusion that spawning occurs in April and May where hitherto spawning in the northwest Pacific was considered to be in August and September. When the two times are put together spawning could possibly take place from early spring through to early fall. Distribution-wise Nakamura feels that this spawning is taking place in the area from 0° N to 26° N. Although larvae have been taken from 0° N to 10° N and none north of 26° he considers the area to 26° N as critical.

The distribution of larvae in the Atlantic is quite scattered. Lutken (1880) reports specimens from 38° N to 25° S latitude and from 74° W to 19° W longitude. Six locations are presented in this range which lead to no conclusions as to the location of a spawning area. However, LaMonte & Marcy (1941) report three specimens from the Gulf Stream off Florida and this paper reports twenty-eight specimens from relatively the same area, along with five from the Gulf of Mexico. The range of these specimens is from 25° N to 34° N latitude and from 74° W to 87° W longitude, with a time range from January to October. This considerably increases the range of spawning heretofore suspected, and gives rise to a hypothesis on the area and time of spawning as occurs in the western north Atlantic.

In the Mediterranean, Sanzo and Sella were able to observe the fishery carefully all year round, with the exception of the winter months. Their conclusions place the spawning time from June to September in the area around Messina at about 38° N. Perhaps the

later time for spawning is due to the temperature gradient in this northern-most area.

Considering only the area reported in this paper, the western north Atlantic, mention should be made of the various times of year female fish have been reported and the stage of ovary development. Study of the times of larval capture and size of the larvae yields additional information concerning the time and area of the spawning population off our coast.

As far back as 1926, Marie Fish, op. cit., described ovaries taken from a fish off the New England coast. This fish was taken in late July and contained ovaries which were immature. The size range of the eggs was from 0.1 mm to 0.55 mm. Lee (1942) reports on thirteen specimens taken by the commercial fishery off New England during the summer of 1941. The ovaries reported were immature with the eggs ranging in size from 24 to 120 micra (0.024 to 0.120 mm). LaMonte and Marcy (1941) report on twenty-five females obtained off Montauk, New York, which were all in an inactive stage. No information has ever been collected on a ripe fish from the New England fishery. In 1944 LaMonte reports ripe ovaries obtained from Cojimar, Cuba, in September, 1942, and data on 25-pound ovaries taken in the same area in August, 1941. Reporting on the size of mature eggs Sanzo (1922) found them to range from 1.60-1.80 mm while Sella (1911) found the range to be 1.67-1.78 mm. In the ovaries the author has in possession, from Havana, Cuba, taken in March, the eggs range in size from 0.43 to 1.21 mm, with the average size being 0.88 mm. One ovary is 388 mm long and 324 mm in circumference while the other is 322 mm long and 217 mm in circumference. The weight is 2685 gms. Considering the size of the mature eggs as found by Sanzo and Sella these ovaries are probably a little more than halfway developed, which might mean they would be spawned out sometime during the summer if the swordfish is an annual spawner.

Corroborating this early spring and summer spawning is the data on the size and time of capture of the larval specimens. Considering first the two specimens taken in the Gulf of Mexico (A1 at 6.1 mm and A2 at 8.2 mm), which were taken in early June, we have concrete evidence of spawning close to that time. According to Sanzo and Sella fertilized eggs hatch in two and one-half days with the larvae reaching a size of about 4 mm in seven days, and a size of about 5.5 mm in nine days. Taking the ratios obtained from these growth data,

an 8 mm specimen would only be about 13 days old. Surface current data in the eastern Gulf (Leipper & Drummond, 1952) limits the distance that could be traveled by a specimen of this size to about 300 miles and would place the spawning area somewhere near the Yucatan Channel. A similar situation exists with the 6.1 mm specimen.

Considering now the specimens taken in the Gulf Stream system, those captured on July 29 and 30, (specimen Nos. 1-19) and one taken on May 10, (specimen No. Reg. 73) give evidence that spawning took place in the Gulf Stream system from around Cay Sal Bank and all along the Florida coast. Specimen No. Reg. 73 at 7.8 mm from about 60 miles south of Cape Hatteras, North Carolina, indicates spawning in the Gulf Stream probably off the coast of Georgia, and perhaps further north. Temperatures of 28° and 29° centigrade occur in this region in early spring and no doubt continue a good distance north. Thus we must assume that spawning occurs in the Gulf Stream system almost at the same time as in the Gulf of Mexico, as ascertained from the smaller specimens; in the Gulf of Mexico early May and June and in the Gulf Stream late April through July. Considering the other specimens captured, both in the Gulf and in the Gulf Stream, the spawning time and area are affected. If an approximate growth factor is calculated from the data of Sanzo (1922) and is applied (as a guess) to the different sizes of larval specimens captured, a relative date can be approximated for the spawning time of each size. The author realizes that this tentative growth ratio is not accurate as the rate of growth at small sizes generally exceeds later growth ratios. However, it is felt that in this case a guess at the spawning times of the larger specimens might lead to a better idea of the extent of time and area over which spawning takes place. The ratio as calculated from Sanzo's data gives the factor of 0.6 mm growth in length per day. When applied to specimen No. S.C. at 192.1 mm it indicates spawning in July. Keeping in mind the fact that this specimen was captured about 60 miles southeast of Cape Hatteras, North Carolina, and in the area of the approximate axis of the Gulf Stream, back calculation would place its spawning time in July and probably in the northern Caribbean. Like calculations for other specimens result in an extension of time of spawning from the end of December through the end of September and place the area from the lower Caribbean through the Yucatan Channel, the Straits of Florida and the Gulf Stream system north to the South Carolina coast. In terms of latitude this area would include from about 15° N to about 32° N. The location of the Gulf

TABLE 5. STOMACH CONTENTS OF 27 LARVAL SWORDFISH TAKEN BY THE
U.S.F.W.S. T.N. GILL.

<i>Stomach Contents</i>		
<i>Specimen No.</i>	<i>Size in mm.</i>	
Reg. 73	7.8	Not dissected, but 2 copepods evident
18	9.0	26 Calanoid copepods
19	12.1	2 fish heads, 2.3 & 1.3 mm
17	14.5	2 fish eyes and 17 lenses
15	18.2	1 Scombrid-like head, 3.2 mm
		1 larva, 5.1 mm
8	20.2	1 Scombrid-like head, 2.3 mm
		1 fish head, 2.1 mm
		1 Scombrid larva, 6.5 mm
9	20.4	1 Gempylid-like head, 2.6 mm
		1 Istiophorid-like larva, 2.3 mm
		1 Exocoetid larva, 4.4 mm
11	20.7	1 fish head, 2.3 mm
		1 Scombrid larva, 7.1 mm
16	20.8	1 fish head, 3.0 mm
		1 larva, 5.6 mm
6	21.2	1 fish snout, 1.4 mm
		1 Scombrid larva, 8.2 mm
12	21.9	2 fish heads, 1.3 & 2.6 mm
		1 <i>Istiophorus americanus</i> , 6.0 mm (standard length)
13	22.1	1 fish head, 2.3 mm
		2 larvae, 4.3 & 4.7 mm
5	22.1	3 fish heads, 2.5, 2.0 and 1.8 mm
7	24.8	1 <i>Xiphias gladius</i> head: (snout 2.3 mm, mandible 3.4 mm; whole fish between 8.5-9.5 mm as indicated from table 2)
		1 Scombrid larva, 5.8 mm
10	25.8	Bits of flesh, 2 fish eyes
14	25.8	2 Scombrid larvae, 7.1 & 6.6 mm
		1 fish snout, 1.9 mm.
		Bits of flesh
4	27.2	2 fish heads, 3.6 & 2.9 mm
3	28.0	2 fish heads, 2.7 & 2.0 mm
		1 larva, 4.0 mm
		1 eye
Reg. 61	28.6	Gut ruptured during capture
2	28.7	1 Scombrid head, 4.6 mm
		1 fish jaw, 1.5 mm
		Bits of flesh
Reg. 39	33.0	1 <i>Coryphaena hippurus</i> , 9.4 mm
		1 larva, 5.9 mm
		Bits of flesh
1	34.4	1 Gempylid-like head, 4.5 mm
		1 fish head, 3.5 mm
		1 Exocoetid, 5.6 mm
T.O. 1	43.7	3 fish heads, 4.7, 4.2 and 3.6 mm
Reg. 17	68.8	2 larvae, 4.1 & 3.4 mm
		9 fish eyes
		Bits of flesh
Reg. 53	70.0	1 <i>Xiphias gladius</i> , 13.6 mm
		2 larvae, 6.0 & 7.4 mm (caudal region missing on latter)
		1 fish head, 2.5 mm
		Bits of flesh
Reg. 72	72.5	Bits of flesh
S.C.	192.1	Bits of flesh

of Mexico specimens further substantiates the theory that spawning occurs in the lower Caribbean, as the major currents moving north from the Caribbean into the Gulf of Mexico do not swing farther west than 88° . Specimen A5 at 55.4 mm would most likely have come from the Caribbean taking into account the current structure. This specimen may have been spawned around the first of March somewhere south of Jamaica. Incidentally the surface temperature in this area at this time of the year approximates 80° F., which is the surface temperature in the area where the smallest specimens were taken in July.

It is acknowledged that the wide limits placed on spawning area and spawning time are largely theory based on the data obtained to date. This applies both to number and place of capture of larval specimens, and to the growth rate of young fish as deduced from Sanzo (1922). LaMonte & Marcy (1941) believe that the growth rate of the swordfish is rapid, which if true, will tend to cut down the wide spawning area presented here. Additional information is needed and much could be obtained from the commercial fishery of Cuba as well as a study in the region south of the Yucatan Channel for indications of what might be occurring farther south in the Caribbean.

STOMACH CONTENTS

Table 5 lists the stomach contents of 27 larval swordfish taken from the *T. N. Gill*. Only in the cases of the 7.8 and 9.0 mm specimens were any zooplankton found. All the rest of the stomachs contained fish larvae or parts thereof. The larvae that could be identified were restricted to surface fishes namely, Scombrids, Exocoetids, Xiphiids and Istiophorids. In most instances the stomachs were gorged giving rise to the distorted body depth measurements mentioned above. The 6.0 mm sailfish found in the 21.9 mm specimen was in perfect condition, and it is interesting to note that at the time of capture of this specimen 15 specimens of larval sailfish were also taken ranging from 3.4 to 21.0 mm in standard length.

NOTE

After the manuscript had gone into final proof one additional specimen was obtained from a *T. N. GILL* cruise. The measurements, counts, percentages of standard length, body proportions and stomach contents of this specimen are tabulated as follows:

U.S.F.W.S. *T. N. GILL* Cruise 6

Station No. Reg. 10

Date. April 27, 1954

Position. 28° 19'N latitude and 80° 10'W longitude

Time. 0307

Specimen No. Reg. 10

Size in mm 48.6

Method of capture. Dip net

<i>Specimen No.</i>	<i>Reg. 10</i>	<i>% Std. L.</i>	<i>Body Proportions</i>	<i>Stomach Contents</i>	
Standard length	48.6mm	—	SL/ML	1.02	2 fish eyes Bits of flesh
Total length	52.7	—	HL/SL	1.29	
Body	26.8	55.1	HL/ML	1.32	
Head	21.5	44.2	HL/ED	11.32	
Snout	16.7	34.4	HL/Po	7.41	
Mandible	16.3	33.5	Std. L/HL	2.26	
Maxillary	3.1	6.4	Std. L/BL	1.81	
Postorbital	2.9	6.0	Std. L/ED	25.58	
Caudal fin length	4.1	8.4	Std. L/SL	2.91	
Snout to dorsal origin	22.4	46.1	Std. L/ML	2.98	
Snout to anal origin	36.2	74.5	Std. L/CFL	11.85	
Snout to pectoral origin	21.1	43.4	Std. L/HD	13.89	
Greatest depth	3.3	6.8			
Head depth	3.5	7.2			
Depth at anus	1.6	3.3			
Depth at peduncle (ant. margin)	1.3	2.7			
Depth of snout (post. margin)	1.9	3.9			
Eye diameter	1.9	3.9			
Dorsal base	24.1	49.6			
Anal base	8.1	16.7			
Pectoral base	0.6	1.2			
Dorsal rays (number)	48				
Anal rays (number)	16				
Pectoral rays (number)	17				

APPENDIX I

Temperature, Salinity and Oxygen Concentrations

In Table 6 are shown the surface salinities, temperatures and oxygen concentrations taken on stations approximating the axis of the Gulf Stream for those cruises on which young swordfish were captured. Too few specimens were taken to justify an attempt at correlation with these factors. The data are presented to make available the actual conditions existing at the time and place the specimens were obtained.

TABLE 6. (Continued)

Station No.	Position		CRUISE 2		CRUISE 3		CRUISE 4	
	Lat. N	Long. W	April 23-May 12, 1953	July 25-August 12, 1953	Oct. 7-Nov. 8, 1953	MI/I	MI/I	%
			°C	°C	%			
51	32° 20'	77° 30.5'	—	29.14	36.01	4.58	—	36.22
52	32° 35'	77° 47'	—	29.19	36.04	4.54	—	36.13
53	32° 49'	78° 03.5'	24.57*	28.11	35.43	4.73*	—	36.09
60	33° 08'	77° 20'	21.75	27.91	35.94	5.04	—	36.17
61	32° 54'	77° 03'	24.08*	27.91	35.68	4.75*	—	36.29
62	32° 39.5'	76° 46'	25.93	28.81	36.02	4.57	—	36.27
63	33° 15'	76° 22'	25.04	28.42	36.04	4.61	—	36.21
64	33° 28.5'	76° 39'	23.62	27.62	35.84	4.91	—	36.25
71	34° 03.5'	76° 15'	25.23	28.15	35.95	4.71	—	—
72	33° 50'	75° 58'	25.40*	28.70	36.07	4.63*	—	—
73	34° 11'	75° 19'	25.74*	—	—	4.63*	—	—
74	34° 25.5'	75° 36'	25.98	—	—	4.41	—	—
79	34° 54'	75° 04'	25.35	—	—	4.71	—	—
80	34° 40'	74° 46.5'	25.69	—	—	4.55	—	—
Sp. Sta. 1	34° 00'	74° 00'	—	—	—	—	—	—
T. O. 1	24° 37'	77° 18'	—	—	—	—	—	36.17*

*Stations where specimens of *Xiphias gladius* were captured.

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PARASITES OF MARINE FISHES OF THE MIAMI REGION

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ABSTRACT

Helminth parasites were collected from the viscera of nine species of marine fishes caught off Miami, Florida. The list of parasites includes fifteen species, as follows: four species of Trematoda, six species of Cestoda, three species of Acanthocephala (one representing a new genus), and two species of Nematoda. The discussion of each parasite includes a comparison of specimens reported here with those reported by other investigators.

INTRODUCTION

During the month of August, 1952, the viscera of a number of marine fishes, caught in the waters off Miami, Florida, were examined for helminth parasites. Most of the viscera were obtained at Pier Five, Miami, from fish brought in by the charter boats. Some material was obtained from fish caught from a head boat, *the Sylva*. Representatives of the four major groups of helminth parasites were found in these fishes; these are listed in Table 1. Among the trematodes, four genera belonging to two families of the Digenea are represented. Since the gills and mouth cavity were not examined, no monogenetic forms were found. It is possible that a greater variety of Digenea would have been found if it had been possible to examine all fishes immediately. Since they were often kept over night in the refrigerator it is likely that many of these worms were overlooked, as they are very delicate and die very soon after the death of the host. Only one species of adult cestode was found. This was the pseudophyllidean, *Bothriocephalus manubriiformis* (Linton), which occurred in large numbers in the intestine of the sailfish, *Istiophorus americanus* Cuvier and Valenciennes. Five species of cestodes belonging to the order Trypanorhyncha were found in the postlarval, or plerocercus, stage in the body cavity or viscera of a number of teleostean fishes. These forms become mature in the spiral valve of selachians. Two species of the acanthocephalan family Gorgorhynchidae were found, one in the bonito and one in the permit. An acanthocephalan belonging to the family Neoechinorhynchidae was found in the mullet; this represents a new genus and species, *Floridosentis elongatus* Ward, 1953. A number of large nematodes, *Contracaecum histiophori* Yamaguti, were found in the sailfish stomachs, and a nematode belonging to the genus *Spirocamallanus* was found in the body cavity of a schoolmaster snapper.

TABLE I

LIST OF PARASITES COLLECTED FROM FISHES CAUGHT IN THE VICINITY OF
MIAMI, FLORIDA

Host	Number Examined	Parasite	Number of Fish Infected
<i>Coryphaena hippurus</i> Linnaeus, dolphin	5	<i>Dinurus tornatus</i>	4
		<i>Hirudinella marina</i>	1
		<i>Nybelinia bisculata</i>	3
		<i>Tentacularia coryphaenae</i>	2
<i>Istiophorus americanus</i> Cuvier and Valenciennes, sailfish	4	<i>Bothriocephalus manubriiformis</i>	3
		<i>Contracaecum histiophori</i>	2
		<i>Hirudinella marina</i>	3
<i>Lutianus apodus</i> Walbaum, schoolmaster snapper	1	<i>Spirocamallanus</i> sp.	1
<i>Mugil cephalus</i> Linnaeus, mullet	10	<i>Floridosentis elongatus</i>	5
<i>Euthynnus</i> sp. Fraser-Brunner* 1950	32	<i>Callitetrarhynchus gracilis</i>	17
		<i>Hirudinella marina</i>	4
		<i>Nipporhynchus ornatus</i>	5
<i>Scomberomorus cavalla</i> (Cuv. and Val.), kingfish	2	<i>Bucephalopsis arcuatus</i>	1
		<i>Tentacularia coryphaenae</i>	1
<i>Seriola dumerili</i> Risso, amberjack	1	<i>Dasyrhynchus variouncinnatus</i>	1
<i>Sphyrna barracuda</i> (Walbaum), barracuda	19	<i>Bucephalopsis arcuatus</i>	3
		<i>Pseudotobothrium dipsacum</i>	1
		<i>Rhipidocotyle longleyi</i>	1
<i>Trachinotus falcatus</i> (Linnaeus)	1	<i>Serrasentis socialis</i>	1

*Two species are commonly referred to as bonito in the Miami area: *Euthynnus alleterata*, the common bonito, and *Katsuwonus pelamis*. Recent work has indicated that both of these species should be placed in the Genus *Euthynnus* (Fraser-Brunner, 1950).

After removal from the host, the parasites were fixed in Carnoy's fluid (6 parts ethyl alcohol, 3 parts chloroform, 1 part glacial acetic acid) or AFA fixative (alcohol, formalin, acetic acid); they were then transferred to 80% alcohol for storage. The trematodes, cestodes and acanthocephalans were stained with Mayer's paracarmine or Semi-chon's carmine, and studies were made from whole mounts. The nematodes were cleared with lactophenol and studied in that medium.

Linton made a number of surveys of parasites of marine fishes of the Woods Hole, Massachusetts, region over a long period of years (1889-1940). He also made surveys at Tortugas, Florida (1908) and at Beaufort, North Carolina (1905). Most of the parasites collected at Miami seem to be represented in Linton's collections, but some of his descriptions are so brief that it is difficult to make accurate comparisons.

Manter (1934, 1940, 1947) has given detailed descriptions of

trematodes from fishes at Tortugas. He found the giant leech-like trematode, *Hirudinella*, in the dolphin. At Miami it was found in the sailfish and bonito as well as the dolphin. The other host records for trematodes in the writer's collection correspond to those of Manter.

A survey of parasites of fish caught in Galveston Bay was made by Chandler in 1935. He found the same general groups of helminths as those of the writer, but his collection differs considerably as to the species and genera of parasites.

Bangham (1940) made an extensive study of parasites of freshwater fishes of southern Florida. However, the forms harbored by freshwater fishes are, as a rule, quite different from those in marine hosts.

In making taxonomic identifications the chief references used were *The Trematoda* by Dawes (1946), *The Zoology of Tapeworms* by Wardle and McLeod (1952), *Etudes critiques sur les Tétrarhynques du muséum de Paris* by Dollfus (1942), and *Acanthocephala* by Meyer (1933).

The writer wishes to express her sincere appreciation to Dr. F. G. Walton Smith and his staff for use of the facilities of the University of Miami Marine Laboratory while collecting the parasites reported in this paper.

TREMATODA

Family BUCEPHALIDAE

Bucephalopsis arcuatus (Linton, 1900)

Hosts: *Sphyræna barracuda* (Walbaum), barracuda

Scomberomorus cavalla (Cuv. and Val.), kingfish

Large numbers of these parasites were collected from the caeca and intestine of some of the barracudas and smaller numbers from the kingfish. The specimens from the barracuda measure 2 to 3 mm in length and about 0.20 mm in maximum breadth. The anterior sucker is about 0.12 mm in diameter and the pharynx about 0.08 mm. The ova measure about 0.02 by 0.012 mm. The specimens from the kingfish are slightly smaller (2 to 2.8 mm. in length) and the anterior sucker is smaller (0.09 mm in diameter); otherwise they are very similar.

Manter (1940) reported this parasite from the barracuda at Tortugas, Florida. His specimens differ from those of the writer in the following respects: they are shorter and broader, and the suckers are

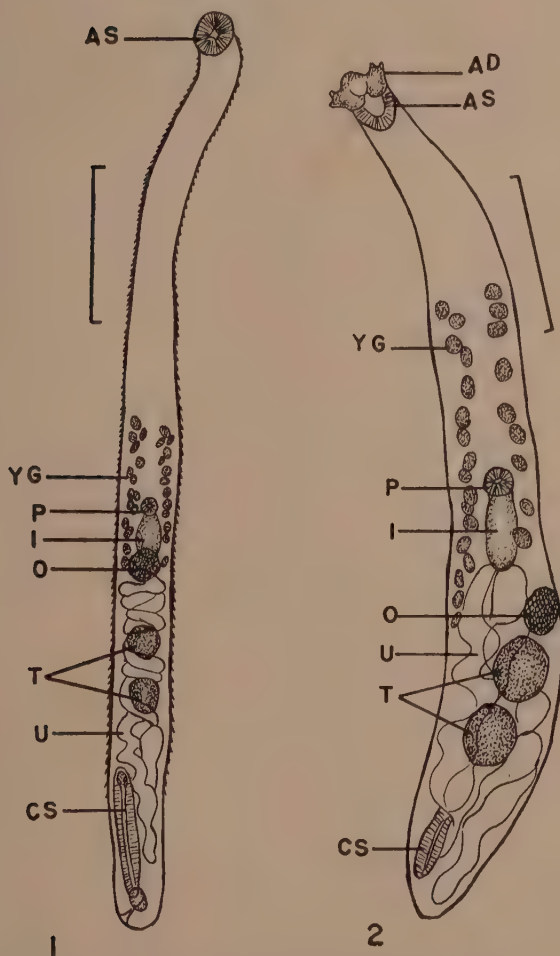


Fig. 1. *Bucephalopsis arcuatus*, adult. Scale has value of 0.5 mm.¹

Abbreviations used: AD, anterior disc; AS, anterior sucker; B, bursa; BO, bothridia; BS, body spines; BU, bulb; CG, cement gland; CR, cement receptacle; CS, cirrus sac; GN, giant nucleus; I, intestine; LEM, lemnisci; O, ovary; P, pharynx; PRO, proboscis; REC, proboscis receptacle; S, proboscis sheath; T, testes; U, uterus; VS, ventral sucker; YG, yolk glands.

Fig. 2. *Rhipidocotyle longleyi*, adult. Scale has value of 0.5 mm.

¹All figures drawn with the aid of microprojection.

smaller in size; the arrangement of the internal organs is slightly different. These differences may be explained in part by the degree of contraction or relaxation at the time of fixation. Dawes (1947, p. 154), concerning *Bucephalopsis gracilis*, states that "mass fixation leads to very great differences in shape, with consequent alteration in the arrangement of the internal organs."

Linton (1905) reported these parasites as *Gasterostomum arcuatum* from the kingfish, *Scomberomorus regalis* (Bloch), and the jack, *Caranx hippos* (Linnaeus), at Beaufort, North Carolina. His specimens from the kingfish are longer (4.2 mm) than those of the writer. It is worth noting that Linton's figure shows a constriction in the body just back of the anterior sucker, while this constriction is not shown in Linton's (1940) figure of this species from other hosts. Similarly, among the writer's specimens, those from the kingfish show the constriction while those from the barracuda do not. Linton (1940) reported this parasite from the bonito, *Sarda sarda* (Bloch), the common mackerel, *Scomber scombrus* Linnaeus, the cutlassfish, *Trichiurus lepturus* Linnaeus, and the common codfish, *Gadus morrhua* Linnaeus, in the Woods Hole region. The measurements of these specimens agree with those of the writer except for the smaller size of the suckers in Linton's specimens. Linton noted much variation in the relative position of the genitalia.

Rhipidocotyle longleyi Manter, 1934, *provis.*

Host: *Sphyræna barracuda* (Walbaum), barracuda

Only three specimens of these parasites were obtained from the intestine of the barracuda, and since they seem to agree very closely with the description of *Rhipidocotyle longleyi*, they are tentatively identified here as this species. They measure 3 to 3.2 mm in length about 0.4 mm in maximum width. The anterior disc measures about 0.2 mm in diameter and the anterior sucker about 0.13 mm in diameter. The pharynx is about 0.12 mm in diameter. The ova measure about 0.026 by 0.012 mm. Manter (1934) described this species from *Hypoclydonia bella* Goode and Bean at Tortugas.

Family HEMIURIDAE

Dinurus tornatus (Rudolphi, 1819)

Host: *Coryphaena hippurus* Linnaeus, dolphin

Several hundred of these helminths were collected from the stomach

of one dolphin and smaller numbers from three others. They measure 2.6 to 4.1 mm in length with the ecsoma extended and 0.5 to 0.9 mm in maximum width. The anterior sucker measures 0.23 to 0.32 mm in diameter and the ventral sucker 0.32 to 0.40 mm. The ova measure about 0.020 by 0.013 mm. Many members of this family are characterized by a tail-like process, the ecsoma, which may be withdrawn into the body proper. This structure is very well developed in the genus *Dinurus*. The writer's specimens are smaller than those described by Looss (1907) (in Dawes, 1947), and the suckers are smaller in size. The measurements given by Looss are as follows: maximum length of body 4.5 mm and maximum breadth 1.3 mm; anterior sucker 0.40 mm in diameter and ventral sucker 0.50 in diameter in medium sized specimens.

In 1947 Manter reported *Dinurus tornatus*, *D. breviductus*, *D. longisinus*, and *D. barbatus* from the dolphin at Tortugas. According to Dawes (1947) all of these are synonyms for *D. tornatus*. In 1940 Linton reported finding a fragment of this parasite in the harvest-fish,

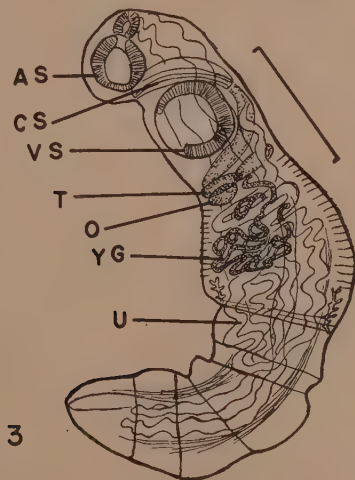


Fig. 3. *Dinurus tornatus*, adult. Scale has value of 1 mm.

Peprilus paru (Linnaeus), at Woods Hole. Linton (1905) reported this as *Distomum tornatum* from the dolphins, *Coryphaena hippurus* Linnaeus and *C. equisetis* Linnaeus, at Beaufort.

Hirudinella marina Garcin, 1730

— Hosts: *Istiophorus americanus* Cuvier and Valenciennes, sailfish
Euthynnus sp. (Cuv. and Val.)
Coryphaena hippurus Linnaeus, dolphin

Not more than three or four worms were recovered from the stomach of each host. The large size and active, muscular movements gave these worms a very striking resemblance to a leech. They measured from 20 to 30 mm in length by 5 to 8 mm in maximum breadth. Many species of this genus have been described, but there is a great deal of confusion in the literature concerning the exact number of species. This may be explained partly by the fact that never more than a few individuals are found in a single host, and also by the fact that the worms are so large and muscular that the arrangement of the internal organs is easily distorted.

Nigrelli and Stunkard (1947) have made a thorough study of this genus, and they regard all forms reported from the wahoo (*Acanthocybium solandri*) as belonging to one species, *Hirudinella ventricosa* Pallas, 1774, and forms from all other hosts as belonging to the species *H. marina* Garcin, 1730. Concerning the forms from fishes other than the wahoo they state, "With the exception of the two specimens from *Katsuwonis pelamis* taken at Bermuda which were immature and may belong to *H. ventricosa*, they are smaller, differ in shape and in the position of the acetabulum, attain sexual maturity at a smaller size, have less powerful suckers and body walls and presumably belong to a different species. All of them appear to belong to a single species which we identify as *H. marina* Garcin."

Manter (1947) reported these worms from the dolphin, *Coryphaena hippurus* Linnaeus, at Tortugas, and tentatively identified them as *Hirudinella ventricosa*; according to Nigrelli and Stunkard they are probably *H. marina*.

CESTODA

Order TRYPANORHYNCHA

These cestodes live as adults in the spiral valve of selachians. The plerocercus, or postlarva, is found free or encysted in the body cavity or visceral organs of many teleosts. This form consists chiefly of a scolex which becomes the scolex of the adult when the final host is reached. Since the scolex of the larva is fully developed and has all of

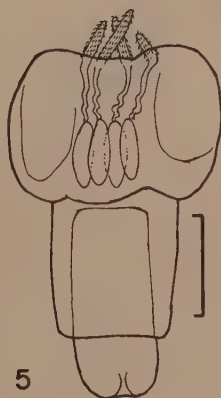
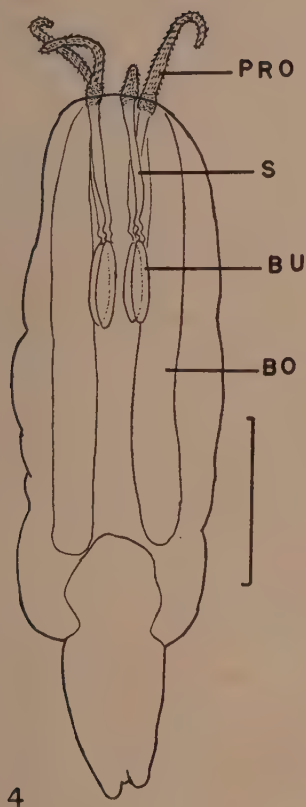


Fig. 4. *Tentacularia coryphaenae*, plerocercus. Scale has value of 1 mm.

Fig. 5. *Nybelinia biscalata*, plerocercus. Scale has value of 0.5 mm.

the characteristics of the scolex of the adult, the species of the larva may be readily determined. In making the following identifications and determinations of synonymy, the chief sources of information were *The Zoology of Tapeworms* by Wardle and McLeod (1952) and *Etudes critiques sur les Tétrarhynques du Muséum de Paris* by Dollfus (1942). The forms reported here are all in the plerocercus or postlarval stage of the life history.

Family TENTACULARIIDAE

Tentacularia coryphaenae (Bosc, 1802)

Hosts: *Coryphaena hippurus* Linnaeus, dolphin
Scomberomorus cavalla (Cuv. and Val.), kingfish

These plerocerci were found in considerable abundance in the body cavity of some hosts. The specimens are about 4 mm long with bothridia about 3 by 0.20 mm and proboscides about 0.70 by 0.50 mm. These forms have been reported from the dolphin at Beaufort, North Carolina (Linton, 1905). Linton (1924) reported them from a number of teleostean fishes in the Woods Hole region, and he reported adults from the sharks, *Carcharhinus milberti* (Müller and Henle), *C. obscurus* (LeSueur), and *Galeocerdo arcticus*, from the same locality. Linton referred to this species as *Tetrarhynchus bicolor* Bartels. Yamaguti (1934) reported the plerocerci from *Euthynnus pelamys* (Linnaeus), and the mackerel, *Scomber japonicus*, and the adults from the sharks, *Prionace glauca* (Linnaeus) and *Scoliodon walbeehmi* (Bleeker), in Japan. The plerocerci have been found in several teleosts in Europe (Dollfus, 1942).

Nybelinia bisculata (Linton, 1889)

Host: *Coryphaena hippurus* Linnaeus, dolphin

These plerocerci were very numerous in the viscera of the dolphin. They measure about 1.1 mm in length by 1 mm in diameter through the bothridia and 0.60 mm in diameter through the region back of the bothridia. The bothridia are about 0.60 mm long. The proboscides measure about 0.40 by 0.05 mm. The bulbs are about 0.20 mm in length. Linton (1889) named this species *Rhynchobothrium bisculatum*. In 1905 he reported it as *Tetrarhynchus bisculatus* from Beaufort, North Carolina; he found the plerocerci in many teleosts and the adults in the sharks, *Carcharhinus milberti* (Müller and Henle), *C. obscurus* (LeSueur) and *Scoliodon terryae-novae* (Richardson). Linton (1924) reported the plerocercus of this parasite from many teleosts and the adult from *Carcharhinus milberti*, *C. obscurus*, *Galeocerdo arcticus*, and *Squalus acanthias* in the Woods Hole region.

Family DASYRHYNCHIDAE

Dasyrhynchus variouncinnatus (Pintner, 1913)

Host: *Seriola dumerili* Risso, amberjack

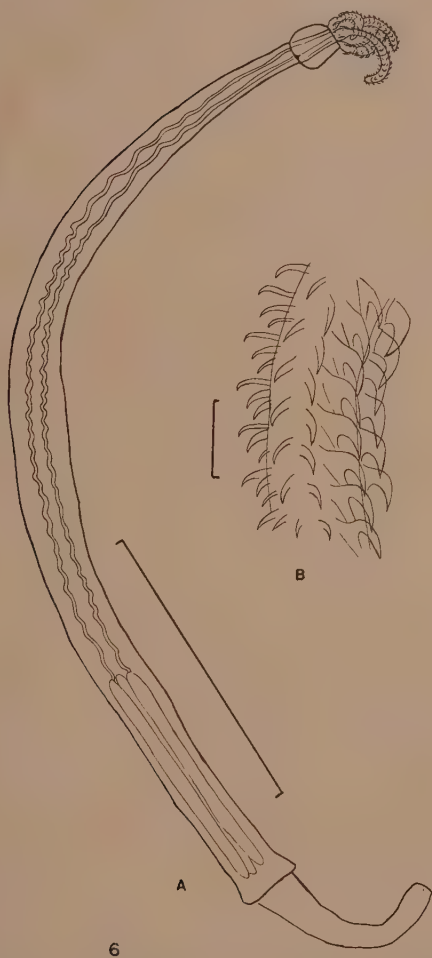


Fig. 6. *Dasyrhynchus variouncinnatus*; A, plerocercus. Scale has value of 5 mm. B, portion of proboscis with hooks. Scale has value of 0.1 mm.

About six plerocerci were found in the body cavity of an amber-jack. Each was covered with a transparent membrane; when this was removed, a large white worm-like structure measuring about 50 by 8 mm began to move quite actively. The scolex of the tapeworm was

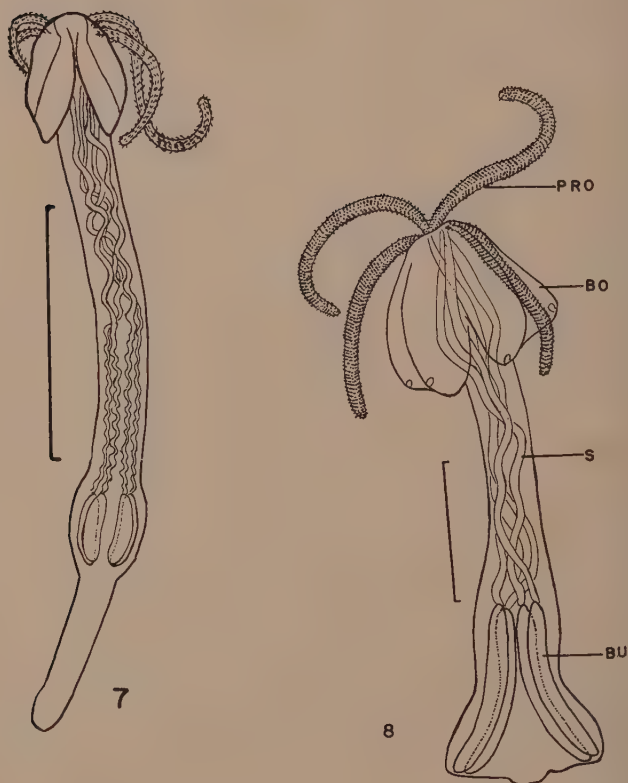


Fig. 7. *Callitetrarhynchus gracilis*, plerocercus. Scale has value of 1 mm.

Fig. 8. *Pseudotobothrium dipsacum*, plerocercus. Scale has value of 1 mm.

enclosed within this, and was removed by dissection. The scolex measured about 16 mm in length with bothridia about 0.70 mm long and 0.60 mm in maximum breadth and proboscides about 1.3 by 0.13 mm. The plerocercus of this species has been reported from several teleosts in Europe (Dollfus, 1942) but no record of its occurrence

in North America has been found. However, the adult has been reported as *Rhynchobothrium insigne* in *Carcharhinus commersonii* Blainville and *C. milberti* (Müller and Henle) at Woods Hole (Linton, 1924). The adult has also been reported as *Tentacularia insignis* from *Hypoprion brevirostris* Poey in the Tortugas region (Shuler, 1938). Chandler (1942) reported it as *Dasyrhynchus insigne* from the shark, *Carcharias platyodon* Jordan and Gilbert, from the Gulf Coast of Florida.

Callitetrarhynchus gracilis (Rudolphi, 1819)

HOST: *Euthynnus* sp. (Cuv. & Val.)

Several encysted larvae were found in the viscera of the bonito. The scolex which was removed from the cyst measured about 3 mm long with bothridia about 0.50 mm long by 0.40 mm in maximum breadth and proboscides about 0.70 by 0.05 mm. Linton (1905) reported the plerocerci as *Rhynchobothrium speciosum* from teleostean fishes and the adult from the shark, *Carcharhinus obscurus* (LeSueur), at Beaufort, and in 1924 he reported the plerocerci from many species of teleosts in the Woods Hole region. The plerocerci were recorded as *Tentacularia lepida* from the catfish, *Galeichthys felis* (Linnaeus), in Galveston Bay (Chandler, 1935). Shuler (1938) reported the adult has *Tentacularia pseudodera* from *Hypoprion brevirostris* Poey in Florida.

Family OTOBOTHRIIDAE

Pseudotobothrium dipsacum (Linton, 1897)

Host: *Sphyraena barracuda* (Walbaum), barracuda

Several plerocerci were removed from the body cavity of a barracuda. After removal from the cyst, the scolex measured about 4.5 mm in length with bothridia about 1.1 mm long by 1.2 mm in maximum diameter and proboscides about 2 by 0.11 mm. These plerocerci were recorded by Linton (1905) as *Otobothrium dipsacum* from several teleosts at Beaufort and in 1924 from teleosts at Woods Hole. The adult of this species is unknown.

Order PSEUDOPHYLLIDEA

Family BOTHRIOCEPHALIDAE

Bothriocephalus manubriiformis (Linton, 1889)

Host: *Istiophorus americanus* Cuvier and Valenciennes, sailfish

Numerous adult specimens were found in the intestine of the sailfish. Each measured about 200 mm in length. Linton (1901) reported this parasite from *Istiophorus nigricans* (= *I. americanus*) and *Tetrapterus albidus* (= *Makalra albida*) at Woods Hole. This species has also been reported from *Istiophorus* sp. in the Indian and Pacific oceans by Shipley (1901). Cooper (1918) studied Linton's material and described this form in great detail.

ACANTHOCEPHALA

Family GORGORHYNCHIDAE

Nipporhynchus ornatus (Van Cleave, 1918)

Host: *Euthynnus* sp. (Cuv. and Val.)

These parasites were very abundant in the intestine of some of the bonitos. In measurements they agree very closely with those given by Van Cleave (1940) for this species. Linton (1892) reported *Echinorhynchus pristis* Rudolphi from the houndfish, *Tylosurus acus* (Lacépède), at Woods Hole and at the same time described *Echinorhynchus pristis tenuicornis* as a variety of *E. pristis*. In 1918 Van Cleave recognized the fact that *tenuicornis* was a distinct species and assigned it to the genus *Rhadinorhynchus*, and at the same time he described as *Rhadinorhynchus ornatus* the material that Linton had referred to as *Echinorhynchus pristis*. In 1934 Chandler described the genus *Nipporhynchus* to include the Japanese species *Rhadinorhynchus katsuwonis* Harada, 1928, from the bonito, *Euthynnus vagrans* (Lesson). In 1940 Van Cleave obtained specimens from the Galapagos Islands in the Pacific from the bonito, *Euthynnus alletteratus* (Rafinesque) and *Katsuwonus pelamis* (Linnaeus), which he recognized as belonging to the species *Rhadinorhynchus ornatus*, and in comparing these specimens with Harada's material, he decided that Harada's species *katsuwonis* was synonymous with *ornatus*; therefore this species was assigned to the genus *Nipporhynchus*.

Linton (1905) reported *Echinorhynchus pristis* from numerous fishes at Beaufort; these specimens were in reality *Rhadinorhynchus tenuicornis*, according to Chandler (1934). In 1908 Linton reported *Echinorhynchus pristis* from the frigate mackerel at Tortugas, but gave no description or drawing of the worm, so that it is impossible to know whether his specimens were *Rhadinorhynchus tenuicornis* or *Nipporhynchus ornatus*.

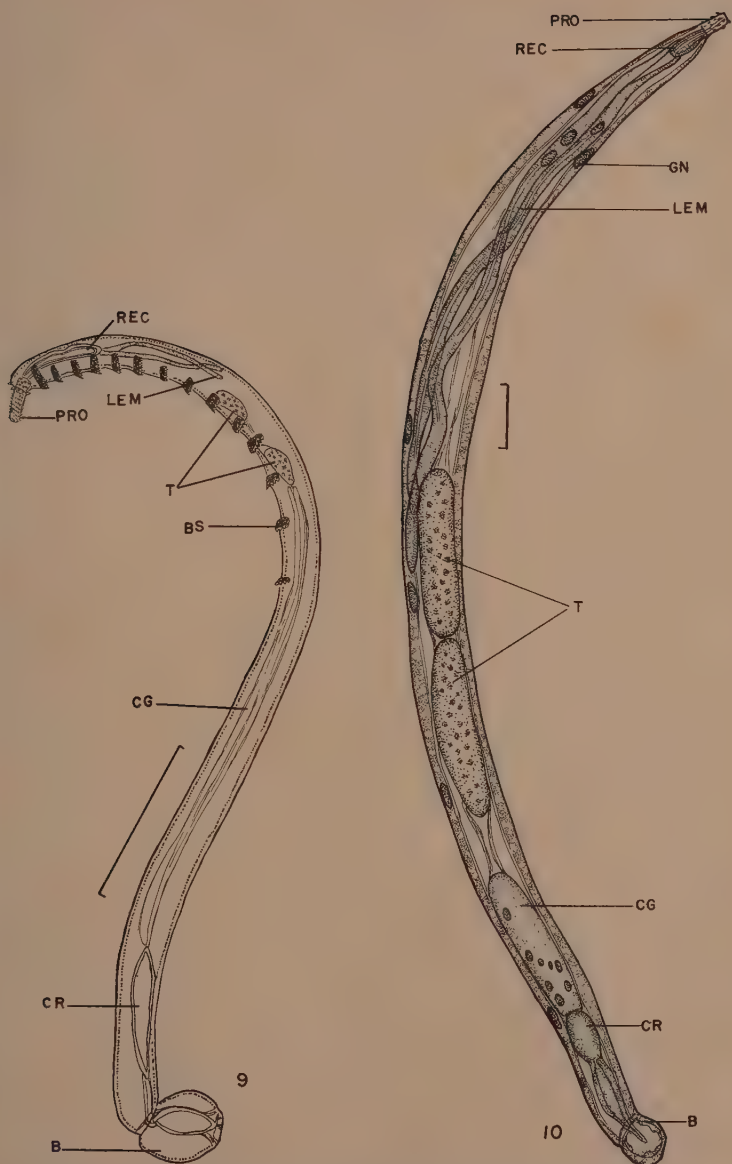


Fig. 9. *Serrasentis socialis*, adult male. Scale has value of 5 mm.

Fig. 10. *Floridosentis elongatus*, adult male. Scale has value of 1 mm.

Serrasentis socialis (Leidy, 1851)Host: *Trachinotus falcatus* (Linnaeus)

About twelve of these parasites were found in the intestine of a permit. This seems to represent a new host recorded for this species. The females measure up to 60 mm in length and the males up to 30 mm. This parasite was described by Linton (1889) as *Echinorhynchus sagittifer* from the Woods Hole region; he found the larval forms encysted in the body cavity of numerous fishes. The encysted forms have also been reported from New Queensland and New South Wales by Johnston and Deland (1929). The adult form was described by Linton (1905) from the cobia (*Rachycentron canadus*) (Linnaeus) at Beaufort, North Carolina. Linton's specimens had a maximum length of 70 mm (females) and 23 mm (males). Linton also found encysted forms in many fishes at Beaufort.

Family NEOECHINORHYNCHIDAE

Floridosentis elongatus Ward, 1953Host: *Mugil cephalus* Linnaeus, mullet

A few acanthocephalans belonging to the family Neoechinorhynchidae were found in each of five mullets. These specimens seemed to differ sufficiently from other members of the family to justify the description of a new genus. Accordingly, the genus *Floridosentis* has been proposed for these parasites, with *F. elongatus* as the genotype; the detailed description of this has been published (Ward, 1953). The chief characteristics of this genus are as follows: Long, slender body, nearly uniform in diameter, slightly enlarged in anterior region. Proboscis cylindrical to club-shaped with eight diagonally longitudinal rows of approximately seven hooks in each row. The anterior hooks are large and provided with conspicuous roots and there is a gradual decrease in the size of the hooks posteriorly. Lemnisci very long and broad, one with two nuclei, the other with one.

This genus is distinguished from other genera chiefly by the number and arrangement of proboscis hooks.

NEMATODA

Family ASCARIDAE

Contracaecum histiophori Yamaguti, 1935Host: *Istiophorus americanus* Cuvier and Valenciennes, sailfish

A number of these large nematodes were found in the sailfish stomachs. The measurements agree with those given by Olsen (1952) who has given a thorough description of this parasite from the Florida sailfish. Yamaguti (1935) described this species from *Histiophorus orientalis* in Japan.

Family CAMALLANIDAE

Spirocamallanus sp.

Host: *Lutianus apodus* Walbaum, schoolmaster snapper

Only two specimens were recovered from the body cavity of the snapper; they are both immature females about 20 mm in length. They resemble very closely *S. monotaxis* Olsen (1952) described from the porgy, *Monotaxis grandoculis* (Forsk.) in Hawaii. However, the mature females are 34 mm long; hence it does not seem feasible to make a positive identification of these worms until mature specimens are obtained.

SUMMARY

Fifteen species of helminth parasites are reported from nine species of marine fish caught in the waters off Miami, Florida. The list of parasites includes four species of Trematoda, six species of Cestoda, three species of Acanthocephala, and two species of Nematoda. One of the parasites from the mullet, *Mugil cephalus* Linnaeus, represents a new genus and species, *Floridosentis elongatus* Ward, 1953 (Acanthocephala). The following host records appear to be new: *Sphyraena barracuda* (Walbaum) as a host for *Rhipidocotyle longleyi* Manter, and *Trachinotus falcatus* (Linnaeus) as a host for *Serrasentis socialis* (Leidy).

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CONTRIBUTIONS will be considered which deal with research in the marine sciences, directly or indirectly related to the southeastern United States and the Caribbean area. Papers dealing solely with the economic or applied aspects of commercial fisheries will not be accepted.

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Bibliographical references must be indicated by author's name and year of publication. References should be listed under that heading in alphabetical order of authors. Each reference should include the last name followed by initials or the first name. Co-authors should be listed with initials preceding the last name. The date should appear next to the author's name, followed by a complete title, in lower case except for the first word. The publisher, city and pagination should follow, in the case of books. The names of periodicals should be abbreviated as in "World List of Scientific Periodicals," Oxford. The volume is then given in arabic numerals underlined for italics, followed by the number in brackets and the pagination preceded by a colon. After the first line of each reference the copy is indented.

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